PB-221 073

DESIGN AND CONSTRUCTION OF A SYSTEM FOR REMOTE OPTICAL SENSING OF EMISSIONS

M. L. Streiff, et al

General Dynamics

Prepared for:

Environmental Protection Agency

October 1972

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

EPA-R2-72-052
October 1972

PB 221 073

Environmental Protection Technology

Design and Construction of a System for Remote Optical Sensing of Emissions

Office of Research and Monitoring
U.S. Environmental Protection Agency
Washington, D.C. 20460

446

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22151

Defense Documentation Center
ATTN: DDC-TC
Cameron Station
Alexandria, Virginia 22314

The attached Department of Defense report has been received in multiple copies. One copy is forwarded herewith for your review. Please indicate disposition by endorsement and RETURN.

Technical Report Number and Date:

Title:

Processor: ____________________

TO: Input Section, NTIS

FROM: DDC-TC

1. ☐ The report has been accessioned as AD ____________________ and is returned herewith.
2. ☐ The report will be accessioned as limited. Please attach the stock copies and send to DDC-TC.
3. ☐ Returned without action. DDC will not accession.

Processor: ____________________

PLEASE DO NOT REMOVE IN CASES 1 AND 3

DOD Report Received in Multiple Copies
NTIS-164 (11-71)

BIBLIOGRAPHIC DATA SHEET

1. Report No.
EPA-R2-72-052

2.

3. Recipient's Accession No.
PB-221 073

4. Title and Subtitle
Design and Construction of a System for Remote Optical Sensing of Emissions

5. Report Date
October 1972

6.

7. Author(s)
M. L. Streiff and C. L. Claysmith

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Convair Aerospace Division of General Dynamics
San Diego, California

10. Project/Task/Work Unit No.

11. Contract/Grant No.
CPA-22-69-142

12. Sponsoring Organization Name and Address
U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Monitoring
Washington, D. C. 20460

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstracts

The report describes the overall and detail instrument design and initial acceptance test performance of a system for remote sensing of emissions. The instrument may be used to measure transmission of urban atmospheres, using a remote source or to measure emission from sources such as smokestacks. It is designed to measure the absorption or emission caused by pollution by scanning spectrally in the 3 to 5.5 micron and 7 to 13.5 micron regions. Data may be recorded on a strip chart recorder, a digital printer, and/or a magnetic tape recorder. The various sections of the report provide: A discussion of the system design followed by a description of component details; Setup procedures and operation; System performance in the laboratory and results of initial field tests; and Maintenance recommendations. The report also contains writing tables and reduced size drawings.

17. Key Words and Document Analysis. 17a. Descriptors

Air pollution
Instruments
Design
Performance
Specifications
Monitoring
Remote sensing
Electronics
Optical measuring instruments
Maintenance

17b. Identifiers/Open-Ended Terms

Air pollution detection

17c. COSATI Field/Group 13B

18. Availability Statement
Unlimited

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page
UNCLASSIFIED

21. No. of Pages
444

22. Price
$6.00/$0.95

FORM NTIS-35 (REV. 3-72)

USCOMM-DC 14952-P72

INSTRUCTIONS FOR COMPLETING FORM NTIS-35 (10-70) (Bibliographic Data Sheet based on COSATI Guidelines to Format Standards for Scientific and Technical Reports Prepared by or for the Federal Government, PB-180 600).

1. **Report Number.** Each individually bound report shall carry a unique alphanumeric designation selected by the performing organization or provided by the sponsoring organization. Use uppercase letters and Arabic numerals only. Examples FASEB-NS-87 and FAA-RD-68-09.

2. Leave blank.

3. **Recipient's Accession Number.** Reserved for use by each report recipient.

4. **Title and Subtitle.** Title should indicate clearly and briefly the subject coverage of the report, and be displayed prominently. Set subtitle, if used, in smaller type or otherwise subordinate it to main title. When a report is prepared in more than one volume, repeat the primary title, add volume number and include subtitle for the specific volume.

5. **Report Date.** Each report shall carry a date indicating at least month and year. Indicate the basis on which it was selected (e.g., date of issue, date of approval, date of preparation.

6. **Performing Organization Code.** Leave blank.

7. **Author(s).** Give name(s) in conventional order (e.g., John R. Doe, or J.Robert Doe). List author's affiliation if it differs from the performing organization.

8. **Performing Organization Report Number.** Insert if performing organization wishes to assign this number.

9. **Performing Organization Name and Address.** Give name, street, city, state, and zip code. List no more than two levels of an organizational hierarchy. Display the name of the organization exactly as it should appear in Government indexes such as **USGRDR-I.**

10. **Project/Task/Work Unit Number.** Use the project, task and work unit numbers under which the report was prepared.

11. **Contract/Grant Number.** Insert contract or grant number under which report was prepared.

12. **Sponsoring Agency Name and Address.** Include zip code.

13. **Type of Report and Period Covered.** Indicate interim, final, etc., and, if applicable, dates covered.

14. **Sponsoring Agency Code.** Leave blank.

15. **Supplementary Notes.** Enter information not included elsewhere but useful, such as: Prepared in cooperation with . . . Translation of . . . Presented at conference of . . . To be published in . . . Supersedes . . . Supplements . . .

16. **Abstract.** Include a brief (200 words or less) factual summary of the most significant information contained in the report. If the report contains a significant bibliography or literature survey, mention it here.

17. **Key Words and Document Analysis. (a). Descriptors.** Select from the Thesaurus of Engineering and Scientific Terms the proper authorized terms that identify the major concept of the research and are sufficiently specific and precise to be used as index entries for cataloging.
(b). Identifiers and Open-Ended Terms. Use identifiers for project names, code names, equipment designators, etc. Use open-ended terms written in descriptor form for those subjects for which no descriptor exists.
(c). COSATI Field/Group. Field and Group assignments are to be taken from the 1965 COSATI Subject Category List. Since the majority of documents are multidisciplinary in nature, the primary Field/Group assignment(s) will be the specific discipline, area of human endeavor, or type of physical object. The application(s) will be cross-referenced with secondary Field/Group assignments that will follow the primary posting(s).

18. **Distribution Statement.** Denote releasability to the public or limitation for reasons other than security for example "Release unlimited". Cite any availability to the public, with address and price.

19 & 20. **Security Classification.** Do not submit classified reports to the National Technical

21. **Number of Pages.** Insert the total number of pages, including this one and unnumbered pages, but excluding distribution list, if any.

22. **Price.** Insert the price set by the National Technical Information Service or the Government Printing Office, if known.

EPA-R2-72-052

DESIGN AND CONSTRUCTION OF A SYSTEM FOR REMOTE OPTICAL SENSING OF EMISSIONS

by

M. L. Streiff and C. L Claysmith
Convair Aerospace Division of General Dynamics
San Diego, California

Contract No. CPA-22-69-142
Program element No. 1A1010

Project Officer: William F. Herget
Division of Chemistry and Physics
National Environmental Research Center
Research Triangle Park, N. C. 27711

Prepared for
OFFICE OF RESEARCH AND MONITORING
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D. C. 20460

October 1972

EPA REVIEW NOTICE

This report has been reviewed by the Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

TABLE OF CONTENTS

Section		Page
	LIST OF FIGURES	viii
	LIST OF WIRING TABLES	xvi
	LIST OF DRAWINGS	xix
1	INTRODUCTION	1-1
2	SPECIFICATIONS	2-1
	System	2-1
	Source and Reference Blackbodies	2-1
	Telescopes	2-3
	Source Modulator	2-3
	Reference Chopper	2-4
	Monochromator	2-4
	Detector	2-4
	Detector Cooler	2-5
	Preamplifier	2-5
	Selective Amplifier	2-6
	Lock-In Amplifier	2-6
	Source Compensation Amplifier	2-7
	Reference Compensation Amplifier	2-7
	Source Digital Voltmeter	2-8
	Ratio Digital Voltmeter	2-8
	Wavenumber Encoder	2-9
	Encoder Control	2-9
	Wavenumber Display	2-9
	Strip Chart Recorder	2-9
	Digital Data Coupler	2-10
	Digital Printer	2-11
	Magnetic Tape Recorder	2-11

TABLE OF CONTENTS
(Continued)

Section Page

3 SYSTEM DESIGN 3-1

3.1 OVERALL SYSTEM REQUIREMENTS 3-1
3.2 SYSTEM DESCRIPTION 3-5
3.3 RADIOMETRY 3-17
3.3.1 Signal Equations 3-17
3.3.2 Etendue 3-35
3.3.3 Transmission 3-51
3.3.4 Modulation Factor 3-56
3.3.5 Spectral Slit Width 3-63
3.4 OPTICAL SYSTEM DESIGN 3-70
3.4.1 Blackbodies 3-70
3.4.2 Telescopes 3-72
3.4.3 Reference Optics 3-79
3.4.4 Monochromator 3-79
3.4.5 Detector Optics 3-86
3.4.6 Detector 3-97
3.4.7 Synch Systems 3-98
3.5 MECHANICAL SYSTEM DESIGN 3-100
3.5.1 Stands 3-100
3.5.2 Telescopes 3-101
3.5.3 Reference Optical System Mounts 3-115
3.5.4 Detector Optical System Mount 3-117
3.5.5 Detector Cooler 3-117
3.5.6 Detector 3-120
3.5.7 Synch Systems 3-120
3.6 ELECTRONIC SYSTEM DESIGN 3-121
3.6.1 The Electronic System 3-121
3.6.2 Signal Sources 3-121
3.6.3 Signal Amplifiers 3-122
3.6.4 Wavenumber Generation 3-125
3.6.5 Data Acquisition Subsystem 3-127
3.6.6 Data Recording Subsystem 3-131
3.6.7 Electronics Calibration 3-135
3.6.8 Power Subsystem 3-135

TABLE OF CONTENTS
(Continued)

Section **Page**

4 COMPONENT DETAILS 4-1

4.1 OPTICAL COMPONENTS 4-1
4.1.1 Blackbodies 4-1
4.1.2 Telescopes 4-5
4.1.3 Reference Optics 4-15
4.1.4 Monochromator 4-17
4.1.5 Detector Optics 4-25
4.1.6 Detector 4-27
4.1.7 Synch Systems 4-34
4.1.8 Alignment Systems 4-34
4.2 MECHANICAL COMPONENTS 4-36
4.2.1 Stands 4-36
4.2.2 Auxiliary Stands 4-43
4.2.3 Electronic Consoles 4-45
4.2.4 Blackbody Plumbing and Mounting 4-45
4.2.5 Telescopes 4-49
4.2.6 Reference Optical System 4-49
4.2.7 Monochromator 4-52
4.2.8 Detector Optical System 4-56
4.2.9 Detector Mount-Dewar 4-58
4.2.10 Detector Cooler 4-58
4.2.11 Synch Systems 4-61
4.3 ELECTRONIC SYSTEM DETAILS 4-63
4.3.1 The Electronic System 4-63
4.3.2 Signal Sources 4-63
4.3.3 Signal Amplifiers 4-68
4.3.4 Wavenumber Generation 4-82
4.3.5 Data Acquisition Subsystem 4-90
4.3.6 Data Recording Subsystem 4-101
4.3.7 Electronics Calibration 4-102
4.3.8 Power Subsystem 4-103

TABLE OF CONTENTS
(Continued)

Section **Page**

5 SYSTEM OPERATION 5-1

5.1 PRELIMINARY CALIBRATIONS 5-1
5.1.1 Blackbody Calibration 5-1
5.1.2 Electronic Calibration 5-1
5.1.3 Monochromator Calibrations 5-3
5.2 SYSTEM INSTALLATION 5-3
5.2.1 Site Selection 5-3
5.2.2 Stand Set Up 5-4
5.3 STARTING THE SYSTEM 5-6
5.3.1 Blackbodies 5-6
5.3.2 Detector Cooler 5-6
5.3.3 Choppers 5-8
5.4 TEST PARAMETER SELECTION 5-9
5.4.1 Spectral Parameters 5-9
5.4.2 Slit Height 5-10
5.4.3 Slit Width 5-10
5.4.4 Time Constant-Scan Speed Relation 5-21
5.4.5 Selective Amplifier Q 5-33
5.5 PROCEDURE 5-37
5.5.1 Monochromator 5-37
5.5.2 Wavenumber Generation System 5-39
5.5.3 Amplifiers-Emission 5-40
5.5.4 Amplifier-Transmission 5-42
5.5.5 Data Recording Systems 5-45
5.5.6 Scanning the Spectrum 5-47
5.6 SYSTEM SHUT DOWN 5-49
5.6.1 Blackbodies 5-49
5.6.2 Detector Cooler 5-50

6 PERFORMANCE 6-1

6.1 LABORATORY TESTS 6-1
6.1.1 Signal 6-1
6.1.2 Noise 6-3

TABLE OF CONTENTS
(Continued)

Section Page

6 PERFORMANCE (Continued)

6.1.3 Typical Scans 6-4
6.2 FIELD TESTS 6-4
6.2.1 Signal 6-7
6.2.2 Noise 6-7
6.2.3 Typical Scans 6-9

7 MAINTENANCE 7-1

7.1 OPTICAL MAINTENANCE 7-1
7.1.1 Blackbodies 7-1
7.1.2 Telescopes 7-1
7.1.3 Reference Optics 7-2
7.1.4 Monochromator 7-2
7.1.5 Detector Optics 7-3
7.1.6 Detector 7-3
7.1.7 Synch System 7-4
7.1.8 Alignment Device 7-4
7.2 MECHANICAL MAINTENANCE 7-4
7.2.1 Stands 7-5
7.2.2 Auxiliary Stands 7-5
7.2.3 Electronic Consoles 7-5
7.2.4 Telescopes 7-5
7.2.5 Reference Optical System 7-5
7.2.6 Monochromator 7-5
7.2.7 Detector Optical System 7-6
7.2.8 Detector Cooler 7-6
7.2.9 Synch Systems 7-6
7.3 ELECTRICAL MAINTENANCE 7-6
7.3.1 Signal Sources 7-6
7.3.2 Signal Amplifiers 7-6
7.3.3 Data Acquisition System 7-6
7.3.4 Data Recording System 7-7
7.3.5 Power Sources 7-7
7.3.6 Fuse List 7-7
8 WIRING TABLES 8-1

8 DRAWINGS (Reduced Size) 9-1

LIST OF FIGURES

Figure	Caption	Page
3.2.1	System Block Diagram	3-6
3.2.2	Photo: Source Stand	3-9
3.2.3	Photo: Receiver Stand-Left Side	3-10
3.2.4	Photo: Receiver Stand - Right Side	3-11
3.2.5	Photo: Electronic Enclosures	3-12
3.2.6	Photo: Counter and DVM's	3-13
3.2.7	Photo: Digital Recorders	3-14
3.2.8	Photo: Data Processor and Control	3-15
3.2.9	Photo: Analog Recorder-Temp. Control	3-16
3.3.1.1	Emission Mode of Operation Schematic Optical Diagram	3-18
3.3.1.2	Transmission Mode of Operation Schematic Optical Diagram	3-24
3.3.1.3	"Decontamination" Schematic	3-30
3.3.2.1	Emission Mode Field of View	3-38
3.3.2.2	Transmission Mode Geometry	3-39
3.3.2.3	Net Transmitting Area - $\theta = 20^\circ$	3-41
3.3.2.4	Net Transmitting Area - $\theta = 30^\circ$	3-42
3.3.2.5	Net Transmitting Area - $\theta = 40^\circ$	3-43
3.3.2.6	Vignetting Factor	3-44

LIST OF FIGURES
(Continued)

Figure	Caption	Page
3.3.2.7	Total Image Height vs Range	3-47
3.3.2.8	Grating Angle	3-48
3.3.2.9	Average Integrated Vignetting Factor	3-49
3.3.2.10	Etendue Ratio	3-50
3.3.3.1	External Specular Transmittance - Irtran 2 (Uncoated)	3-52
3.3.3.2	Aluminum Reflectance	3-53
3.3.3.3	Grating Efficiency	3-55
3.3.4.1	Single Chopper Modulation	3-58
3.3.4.2	Dual Chopper Modulation	3-60
3.3.4.3	Modulation Factor	3-62
3.3.5.1	Image Intensity Distribution	3-64
3.3.5.2	Integrated Output Intensity Distribution	3-64
3.3.5.3	Diffraction Contribution Function	3-66
3.3.5.4	Spectral Slit Width	3-68
3.4.1	Optical System Schematic	3-71
3.4.1.1	Source Blackbody and Ray Envelope; Range = 0.4 km	3-73
3.4.1.2	Source Blackbody and Ray Envelope; Range = 4.0 km	3-74
3.4.2.1	Telescope Performance	3-76
3.4.2.2	Telescope Length Comparison	3-78

LIST OF FIGURES
(Continued)

Figure	Caption	Page
3.4.4.1	Monochromator Optical Diagram	3-81
3.4.4.2	Double Diffraction Limiting Incident Rays	3-83
3.4.4.3	Double Diffraction Wavelength Ranges	3-84
3.4.5.1	Detector Optical Systems	3-87
3.4.5.2	Dall Kirkham + 90 Degree Ellipse	3-89
3.4.5.3	Telescope System + 90 Degree Ellipse	3-90
3.4.5.4	Dall Kirkham + On-Axis Ellipse	3-91
3.4.5.5	Telescope System + On-Axis Ellipse	3-92
3.4.5.6	Dall Kirkham + Detector "Cassegrain" System	3-94
3.4.5.7	Telescope System + Detector "Cassegrain" System	3-95
3.4.5.8	Effect of Monochromator on Emission Mode Performance	3-96
3.4.7.1	Source Synch Receiver	3-99
3.5.2.1	Temperature Differences in a Slab	3-105
3.5.2.2	Telescope Mirror Sections for Thermal Analysis	3-107
3.5.2.3	Transient Temperature Differences in a Telescope Mirror	3-109
3.5.2.4	Telescope Mirror Sections for Thermal Analysis	3-110
3.5.2.5	Temperature vs Time of Telescope Elements	3-113
3.5.2.6	Difference in Position of Focus & Entrance Slit	3-116

LIST OF FIGURES
(Continued)

Figure	Caption	Page
4.1.1.1	Blackbody Warmup History	4-3
4.1.1.2	Blackbody Temperature Profile	4-4
4.1.2.1	Telescope Optical Diagram	4-6
4.1.2.2	Dall-Kirkham System Performance	4-8
4.1.2.3	Telescope System Performance	4-9
4.1.2.4	Telescope Test Source	4-11
4.1.2.5	Telescope Test Set-Up	4-13
4.1.3.1	Reference Optics Diagram	4-16
4.1.4.1	Filter Transmission	4-18
4.1.4.2	Grating Mask	4-19
4.1.4.3	Slit Height Assembly Schematic	4-20
4.1.4.4	Gases Useful for Wavenumber Calibration	4-23
4.1.4.5	Deviations from Wavenumber Linearity	4-24
4.1.5.1	Detector Optics Diagram	4-26
4.1.6.1	Detector Spec. Drawing	4-28
4.1.6.2	Detector Off-Axis Response	4-33
4.2.1	Source and Receiver Assemblies	4-37
4.2.1.1	Stand Assembly	4-38

LIST OF FIGURES
(Continued)

Figure	Caption	Page
4.2.1.2	Stand Pad Details	4-41
4.2.1.3	Stand Wheel Details	4-42
4.2.1.4	Stand Connection Panel	4-44
4.2.4.1	Blackbody Interconnections	4-46
4.2.4.2	Blackbody Geometry & Plumbing	4-48
4.2.5.1	Telescope General Assembly	4-50
4.2.7.1	Monochromator Mount Detail	4-53
4.2.7.2	Wavenumber Drive Details	4-54
4.2.8.1	Detector Optical System Details	4-57
4.2.9.1	Detector Installation	4-59
4.2.10.1	Detector Cooler Details	4-60
4.2.11.1	Reference Synch LED and Photodiode	4-62
4.3.2.1	Detector Circuitry	4-64
4.3.2.2	Reference Synch Detector	4-65
4.3.2.3	Encoder Interconnections	4-66
4.3.2.4	Encoder Dimensions	4-67
4.3.3.1	Preamplifier Interconnections	4-68
4.3.3.2	Selective Amplifier Signal Connections	4-69

LIST OF FIGURES
(Continued)

Figure	Caption	Page
4.3.3.3	Source and Reference Compensation Amp	4-71
4.3.3.4	Source Synch Preamp	4-74
4.3.3.5	Source Synch Preamplifier Interconnections	4-76
4.3.3.6	120 Hz Gyrator	4-77
4.3.3.7	Interconnection of Gyrator	4-78
4.3.3.8	Source and Ref Synch Amplifiers	4-79
4.3.3.9	Source Synch Amplifier Interconnections	4-80
4.3.3.10	Reference Synch Amplifier Interconnections	4-81
4.3.4.1	Data Control Monostable	4-89
4.3.4.2	Interconnection of Data Control	4-89
4.3.5.1	Bi-Directional Counter Interconnections	4-90
4.3.5.2	Sample Hold DVM 5403-015 Interconnections	4-91
4.3.5.3	Ratio DVM 5403-010 Interconnections	4-92
4.3.5.4	I/I_o Ratio Module	4-93
4.3.5.5	I/I_o Block Diagram	4-94
4.3.5.6	I/I_o and Recorder Select Switch Interconnections	4-96
4.3.5.7	Data Coupler Interconnections	4-98
4.3.5.8	Marker Control	4-100

LIST OF FIGURES
(Continued)

Figure	Caption	Page
4.3.6.1	Strip Chart Recorder Interconnections	4-101
4.3.7.1	Standard Signal Generator	4-102
4.3.8.1	±24 V dc Interconnections	4-104
4.3.8.2	±6 Volt Power Supplies	4-105
4.3.8.3	Reference Chopper Motor Drive	4-107
4.3.8.4	Chopper Motor Drive Interconnections	4-108
5.2.2.1	Stand Pad Alignment	5-5
5.3.1	Typical Starting Schedule	5-7
5.4.3.1	Spectral Line Response	5-12
5.4.3.2	$d\nu/dx$ vs s/a	5-14
5.4.3.3	Exit Slit Irradiance	5-15
5.4.3.4	Diffraction Parameters	5-22
5.4.4.1	RC Filter Response	5-24
5.4.4.2	Time Constant - 0.1 cm^{-1} Delay	5-26
5.4.4.3	Time Constant - Peak Error	5-28
5.4.4.4	Time Constant - Scan Speed Logic	5-29
5.4.4.5	Time Per Resolution Element	5-32

LIST OF FIGURES
(Continued)

Figure	Caption	Page
5.4.5.1	Selective Amplifier Relative Response	5-34
5.4.5.2	Selective Amplifier Relative Response Near f_o	5-35
5.4.5.3	Selective Amplifier Phase Response	5-36
6.1.3.1	Typical Laboratory Scans	6-5
6.1.3.2	The R5 Line of CO	6-6
6.1.3.3	Ozone Spectrum	6-6
6.2.3.1	Typical Field Test Scans	6-10

LIST OF WIRING TABLES

		Page
Card Layout		8-1
S1	S2	8-2
S3	S4	8-3
S5	S6	8-4
S7	S8	8-5
S9	S10	8-6
S11	S12	8-7
S13	S14	8-8
S15	S16	8-9
S17	S18	8-10
S19	S20	8-11
S21	S22	8-12
S23	S24	8-13
S25		8-14
J1	P1	8-15
J2	P2	8-16
J101	J102	8-17
P101	P102	8-18

LIST OF WIRING TABLES
(Continued)

		Page
J103	P103	8-19
J104	J105	8-20
P104	P105	8-21
P106	J106	8-22
J107	P107	8-23
J108	P108	8-24
J109	P109	8-25
P110	J110	8-26
P111	J111	8-27
J112	P112	8-28
J113	P113	8-29
J114	P114	8-30
J115	P115	8-31
J116	P116	8-32
J117	P117	8-33
J118	P118	8-34
J119	P119	8-35
J120	P120	8-36

LIST OF WIRING TABLES
(Continued)

Page

Control Panel Wiring 8-37

Coaxial Cables 8-38

Recorder Input SW1 Recorder Input SW2 8-39

Data Acquisition System Cables 8-40

Monochromator Controller 8-41

LIST OF DRAWINGS

Number	Caption	Size (Shts)
596-722-003	General Assembly - Remote Optical Sensing of Emission System	D
004	Mount, Monochromator and Source Blackbody	D(2)
005	Support Structure Assembly	D(5)
006	Stand Assembly	D(5)
007	Optical Components - Reference Optics System	C
008	Optical Components - Detector Optics System	C
009	Dewar Assembly	C
010	Reference Optical System	D(7)
011	Detector Optical System	D(3)
012	Slit Height Assembly	D
013	Modified Wavenumber Drive	D
014	Alignment Devices	D(2);C
015	Encoder Installation	C
016	Cryocooler Equipment	C(2)
017	Source Synch Receiver	D
018	System Nameplate	C
019	Auxiliary Stands	D
020	Electronic Consoles	D

LIST OF DRAWINGS
(Continued)

Number	Caption	Size (Shts)
596-722-021	System Block Diagram	D
022	Recorder Input Switch	C
023	Source Synch Preamp	C
024	120 Hz Gyrator	C
025	Standard Signal Generator	C
026	Source and Reference Synch Amp	C
027	Source and Reference Compensation Amp	C
028	± 6 V Power Supply	C
029	Chopper Motor Drive	C
030	I/I_o Ratio Module	C
031	Data Control Monostable	C
032	Wavenumber Logic Diagram	Special
033	Interconnection Diagram	D
034	Grating Masks	C
035	Recorder Marker Selector	C
036	Elevation Mirror	D(3)

1.0 INTRODUCTION

This report constitutes partial fulfillment of Contract CPA 22-69-142 between the Environmental Protection Agency and General Dynamics/Convair Aerospace (San Diego) and describes the overall and detail instrument design, as well as initial acceptance test performance. The work was performed in the Environmental Sciences Section of the Sensor Technology Group in the Engineering Department of Convair Aerospace. The program leader was Dr. Claus B. Ludwig, assisted by Dr. M. Griggs; they were responsible for the spectroscopic design. M. L. Streiff was responsible for the optical and mechanical design and construction (he conceived the dual chopper system) and performed final system checkout. C. R. Claysmith was responsible for the electronic design and construction. Work started in June 1969 and acceptance tests were performed during 1971. The ROSE system was delivered in early 1972. The government project officers were Mr. John S. Nader and Dr. William F. Herget.

The instrument may be used to measure transmission of urban atmospheres, using a remote source (up to 4 kilometers) or to measure emission from sources such as smokestacks. It is designed to measure the absorption or emission caused by pollution by scanning spectrally in the 3 to 5.5 micron and 7 to 13.5 micron regions. Data may be recorded on a strip chart recorder, a digital printer, and/or a magnetic tape recorder. Digital and analog displays or wavenumber and signal output (either source or reference) and the ratio (transmission) of the source to reference signals are provided. The system is designed to be easily transported for field use.

Details of field tests with this system are given in a separate report under a follow-on contract. This latter contract also covers an elevation mirror to make observation at large vertical angles easier.

In the next section a summary of specifications is given for convenient reference. A discussion of the system design is given in Section 3.0, followed by a description of component details in Section 4.0. Set-up procedures and operation are given in Section 5.0. The system performance in the laboratory and the results of initial field tests are given in Section 6.0 and maintenance recommendations are given in Section 7.0. Wiring Tables are located in Section 8.0 and reduced size drawings are shown in Section 9.0.

Figure numbers are assigned in sequence within each subsection; e.g., the third figure in Section 3.4.2 is designated Figure 3.4.2.3. Pages are numbered within each major section; e.g. the 98th page in Section 3.0 is designated 3-98.

The authors would like to acknowledge the cooperation of many persons during the design and construction of the ROSE system, especially the invaluable discussions with L. L. Acton and G. D. Hall of the Environmental Sciences Section.

We also wish to acknowledge the assistance of L. J. MacDonald of the Purchasing Group and C. N. Abeyta, C. Baker, E. R. Bartle, Dr. W. Malkmus, and L. C. Wilson of the Environmental Sciences Section.

2.0 SPECIFICATIONS

The following condensed specifications are a combination of test data and manufacturer's data (as indicated by an asterisk). Metric and English units are given (except weights and sizes are in English units only). For more complete specification data, refer to the individual component manuals or the Component details section of this report.

System

Design Range:	(Transmission) 0.4 to 4.0 km (0.25 to 2.5 miles)
Spectral Regions:	3 to 5.5 microns (1820 to 3330 cm^{-1})and 7 to 13.5 microns (740 to 1430 cm^{-1})
Resolution:	to 0.01 microns
Scan Time:	2 minutes minimum (either spectral region) 130 minutes maximum (either spectral region)
Display:	Wavenumber, I, I/I_o
Recording:	Analog and digital
Ambient Temperature:	0 to 38°C (32 to 100°F)
Relative Humidity:	0 to 95%
Portability:	All units mounted on casters
Source Power:	115V 60 Hz 1 phase 12 amp start; 8 amp run
Receiver Power:	115V 60Hz 1 phase 32 amp start; 24 amp run

Source and Reference Blackbodies

Mfgr. & Model:	Electro Optical Ind., Santa Barbara, Ca. Model WS135R cavity; Model 916 cooler; Model 216A Temperature control
Max. Temperature:	*1900°K
Operating Temperature:	1800°K

Temperature Stability:	± 4°C
Emissivity:	*0.99 ± 0.01
Aperture:	12.7 x 6.3 mm (0.50 x 0.25in.)
Cooling:	Ethylene glycol closed loop with ambient heat exchanger
Warm-up Time:	Approximately 90 minutes (standby) 195 minutes (cold start)
Lifetime:	*Approximately 700 hours
Aperture Set:	*0.0125, 0.025, 0.05, 0.10, 0.20 inch diameter and wide open (0.562 inch)
Internal Temperature Monitor:	Included
External Radiation Probe:	Included
Power Required:	115V 60 Hz

	Start	Run
Cooler	2.2 amp	2.2 amp
Temperature Control	10	5.8

Weight & Size*	lbs	L	W	H
Cavity	25	12"	8"	10.5"
Cooler	30 (est)	19"	10.5"	11"
Temp. Controller	40	14"	19"	7"

Telescopes

Mfgr. and Model:	Perkin Elmer (Costa Mesa, Ca.) Model 700
Type and f/no:	Dall Kirkham f/5.0
Focal Length:	304.8cm (120 inches)
Clear Aperture:	61.0cm (24 inches)
Field of View:	0.25 degree (±0.125 degrees)
Blur Circle Diameter:	150 microns
Primary f/no:	2.0
Secondary Magnification:	2.5
Mounting Plane to Focus:	30.48cm (12.0 inches)
Overall Tube O.D.:	28 inches
Overall Length:	36 inches
Weight:	130 pounds

Source Modulator

Mfgr. and Model:	Electro Optical Ind. (Santa Barbara, Ca.) Model 311
Frequency*:	30 - 3000 Hz continuously variable (24 slot blade; Freq. = 3.0 x meter rdg)
Operating Freq:	570 Hz
BNC Freq. Monitor*	(PPS = 3.75 x meter rdg)
Stability:	±0.5% (* ±0.1%
Warmup Time:	Approximately 1 hour (to within ±0.5%)
Power Required:	115V 60 Hz 0.3 amp

Reference Chopper

Mfgr:	**Convair**
Frequency:	**330 Hz**
Stability:	**± 0.3 Hz**
Warmup Time:	**Approximately 30 minutes**
Power Required:	**1.2 amp.**

Monochromator

Mfgr. and Model:	Perkin Elmer (Norwalk, Conn.) Model 210B
Type:	Littrow grating with linear wavenumber drive
Gratings:	3 - 5.5μ; 240 l/mm 20° 3400 cm^{-1} (2.94μ) 7 - 13.5μ; 101 l/mm 22°2' 1333 cm^{-1}(7.5μ) Masked to 15.9 cm^2 net area (nominal)
Slits:	Width; 0 to 2.0 mm micrometer controlled Height; 0 to 12.0 mm micrometer controlled
Wavenumber drive:	3/32 to 6 rpm in steps of 2 x
Min. scan time:	Approximately 2 minutes
Scan Control:	Perkin Elmer 012-0466
Size:	17.5" x 24" x 12"
Weight:	64 pounds

Detector

Mfgr. and Model:	Santa Barbara Research Center (Goleta, Ca.) 8679-1
Type:	Mercury doped Germanium
Operating Temp:	26°K (58 psia H_2)
Size:	0.2 x 2.0 mm
Field of View:	90°
D*(λm, 630):	0.84×10^{10}m Hz $^{\frac{1}{2}}$/watt
R(λm, 630):	12.0×10^{4} volts/watt
Resistance:	12.8K

Detector Cooler

Mfgr. and Model:	Cryogenic Technology Inc. (Waltham, Mass.) Model 20 with 3833-005 temperature controller.
Type:	Closed cycle He refrigerator consisting of compressor and cold head connected by flexible hoses.
Operating Temp. Range:	Approximately 16 to 28°K
Operating Temperature:	26°K (58 psia H_2)
Temperature Stability:	± 0.1°K (± 1 psia H_2)
Cooldown Time:	Approximately 15 minutes

Power Required:	115V 60 Hz	Start	Run
	Compressor	~ 15 amp	10 amp
	Temp. Control	~ 0.1	~ 0.1

Size:	Compressor 20"L x 13"W x 13"H Cold Head 8"L x 4"W x 12"H Temp. Controller 11"L x 12"W x 7"H
Weight:	Compressor 70 pounds Cold Head 11 pounds

Preamplifier *

Mfgr. and Model:	Princeton Appl. Research Corp. (Princeton, N.J.) Model 213
Type:	RC coupled, single ended low-noise
Direct Input Impedance:	10 megohms shunted by less than 20 pf (transformer input also available)
Frequency Response	± 0.2 db from 10 Hz to 100 Khz
Gain:	Switch selectable from 1 to 1000 in 1, 2, 5 sequence plus vernier (± 1% at f = 1 Khz)

Noise:	At 300 to 600 Hz and 5,600 ohms source resistance (12.8K in parallel with 10K) the noise figure is about 4 db
Max output:	20V peak to peak @ 100 Khz
Output Impedance:	600 ohms
Power Requirement:	± 24V @ 38 ma (from NIMBIN)
Size:	8.8"H x 2.7"W x 10"L
Weight:	3 lbs

Selective Amplifier *

Mfgr and Model:	Rrinceton Appl. Research Corp. (Princeton N.J.) Model 210
Input Impedance:	1 megohm shunted by less than 20 pf (thru 0.5 uF)
Frequency Range:	1 Hz to 110 KHz
Frequency Stability:*	0.02%/°C typical; 0.02%/24 hr at constant temp.
Q Range:	1 to 100 in 1, 2, 5 sequence
Gain:	1 or 10
Max Output:	5 volts RMS
Output Impedance:	600 ohms
Power Requirement:	± 24V @ 100 ma (from NIMBIN)
Size:	8.8"H x 2.7"W x 10"L
Weight:	4 lbs.

Lock-In Amplifier *

Mfgr and Model:	Princeton Appl. Research Corp. (Princeton, N.J.) Model 220A
Input Impedance:	1 megohm shunted by 30 pf

Frequency Range: 1 Hz to 110 KHz

Sensitivity: 0.1, 0.2, 0.5 or 1.0 volts rms input for full scale ± 10V DC output (referred to as gains of 100, 50, 20 or 10 respectively)

Time Constant: 0.03 ms to 1 second in 1, 3, 10 sequence
6 db per octave roll-off

Linearity*: Better than 0.1% of full scale

Max Output: ± 10V DC

Output Impedance: Direct Mixer = 100 ohms Monitor = 5,000 ohms

Synch Input Impedance: 10K ohms

Synch Modes: Sel Ext (used for normal operation), Ext., Int., Int 2F and Cal 10 mv.

Synch Output Impedance (Cal Output): 50 ohms

Calibration Output: 18 mv pp square wave (8.1 mv rms fundamental)

Source Compensation Amplifier

Mfgr and Model: Convair; no model number

Type: Non-inverting operational amplifier

Input Impedance: ~ 400 megohms

Gain: 8.0

Output Impedance: < 1 ohm

Reference Compensation Amplifier

Mfgr and Model: Convair; no model number

Type: Differential operational amplifier
Source signal; + input
Reference signal; - input

Input Impedance: ~ 400 megohms

Gain: 1.00

Output Impedance: < 1 ohm

Source Digital Voltmeter *

Mfgr and Model: Dana Labs Inc. (Irvine, Calif.) Model 5403 with Model 015 plug-in sample and hold; 66-D2 isolated output option

Input Impedance: 10V range, 1000 megohms; other ranges 10 megohms

Accuracy: ± 0.01% of reading ± 0.01% of full scale

Temp. Coeff: 0.001% of full scale/°C

Display: Five digits plus decimal point

Maximum Display: 10.999 volts

May be programmed to read on manual or external system command

Power Requirements: 115V 60 Hz 0.4 amp

Size: 19"W x 17"L x 5"H

Weight: 25 lbs.

Ratio Digital Voltmeter *

Mfgr and Model: Dana Labs. Inc. (Irvine, Calif.) Model 5403 with Model 010 plug in (DC and ratio; 66-D2 isolated output option

Input Impedance 10V range, 1000 megohms; other ranges 10 megohms

Accuracy: ±0.01% of reading ± 0.01% of full scale

Temp. Coeff: 0.001% of full scale/°C

Display: Five digits plus decimal point (10 x ratio)

Maximum Display: 10.999 (ratio = 1.0999)

May be programmed to read automatically or on external system command

Power Requirement: 115V 60 Hz 0.4 amp

Size: 19W x 17"L x 5"H

Weight: 25 lbs

Wavenumber Encoder

Mfgr and Model: Dynamics Research Corp. (Stoneham, Mass.)
Model 35-1-001-9000

Counts per Revolution: 9000

Power Requirements: + 6V @ 0.31 amp; - 6V @ 0.04 amp

Encoder Control

Mfgr and Model: Convair; no model number

Type: Bidirectional logic with variable slope

Slope Range: 3 - 5.5 micron; 112.5 to 144.5cm^{-1}/turn
7 - 13.5 micron; 50.0 to 56.8cm^{-1}/turn
(Slope dial in units of 0.1cm^{-1}/wavenumber drum turn)

Wavenumber Display

Mfgr and Model: Anadex Instr. (Van Nuys, Calif.)
Model CB600R (options BZ, BL, G-4A, A)

Input Impedance: 1 megohm in parallel with 80 pf

Display: 5 digits

Maximum Display: 99999 (9999.9cm^{-1})
Preset switch for setting wavenumber for zero on wavenumber drum.

Power Requirement: 115V 60 Hz 0.3 amp

Size: 19"W x 12"L x 3.5"H

Weight: 15 lbs

Strip Chart Recorder *

Mfgr and Model: Hewlett Packard (Palo Alto, Calif.)
Model 7701B with Model 8801A plug in
(heated stylus)

Input Impedance: Balanced to gnd; 500K ohm ± 1% in parallel with 100 pf each side

Strip Chart Recorder (continued)

Input Ranges: 5 mv to 5 volts/div in 1, 2, 5 sequence
Frequency Response: DC to 30 Hz
Linearity: 0.25 div.
Gain Stability: 0.035%/°C; 0.06%/% line voltage
Chart Speeds: 0.5, 2.5, 10 or 50 mm/sec or mm/min.
Chart: 10m wide (50 div full scale)
time lines every 5 mm
Perma paper 651-217 (200 ft)
Event Marker: Included
Power Requirement: 115V 60 Hz 0.6 amp
Size: 19"W x 17.5"L x 14"H (in rack mtg adapter)
Weight: 20 lbs

Digital Data Coupler *

Mfgr and Model: Zehntel Inc., Berkley, Calif. Model 649
Type: Custom built to accept data from digital voltmeters and counters and transfer the data to the tape recorder and/or the digital printer with proper data format conversion.
Modes and Cycle Time: Record Only; 26 ms + reading time
Print Only; 50 ms + reading time
Record and Print; 50 ms + reading time
Reading time approx. 2 to 3 ms normally without range change.)
Power Requirement: 115V 60 Hz 0.3 amp

Digital Printer *

Mfgr and Model:	Hewlett Packard (Palo Alto, Calif.) Model 5050B
Data Input:	Parallel entry BCD;"1" state positive
Printing Rate:	20 lines/second
Column Capacity:	18 columns
Output Format:	I, 4 columns; I/I_o,4 columns; Wavenumber, 5 columns
Paper:	Pressure sensitive (9281-0387; 15,000 lines/pack)
Power Requirement:	115V 60 Hz 0.8 amp

Magnetic Tape Recorder *

Mfgr and Model:	Kennedy Co. (Altedena, Calif.) Model 1600/H5
Date Input:	
Recording Rate:	500 characters per second
Tape Format:	7 track NRZI (6 data cha. plus parity)
Tape Used:	0.5" wide 1.5 mil computer tape (up to 8.5" dia reels IBM compatible)
Power Requirement:	115V 60 Hz 0.8 amp
Size:	19" W x 10"L x 12.2"H
Weight:	40 lbs

3.0 SYSTEM DESIGN

After setting forth the system requirements in Section 3.1 in terms of the contract,a brief description of the system is given in Section 3.2. System radiometry is set forth in Section 3.3, in which equations for the signal for both the emission and transmission modes of operation and an evaluation of the required parameters are given. The system design per se is divided into three sections: 3.4 Optical System Design, 3.5 Mechanical System Design, and 3.6 Electronic System Design. Emphasis is given in these sections to operational characteristics particularly as they are related to the system. Component details are given later in Section 4.0.

3.1 OVERALL SYSTEM REQUIREMENTS

The overall system requirements are defined by the Contract (CPA 22-69-142) from which the following scope of work is taken.

Article 1. Scope of Work

The Contractor, as an independent organization and not as an agent of the Government, using his best efforts within the time and funds allotted, shall furnish the necessary labor, material and facilities (unless otherwise specified herein) to perform the following work and services:

A. Statement of Work

The contractor shall design, develop, construct, calibrate, performance check-out, and deliver a field-type research IR scanning spectrophotometer with compatible light source for long-path operation. The design and performance requirements include: capability for remote sensing and recording of emission spectra of hot pollutant gases (ranging in temperature from 300° to 600° F. and in concentration from 250 to 3500 parts per million) from stack sources over optical path lengths up to 300 meters with a viewing angle not to exceed 0.5 degrees; capability for sensing and recording absorption spectra for pollutant gases (in concentrations ranging from 0.01 to 1.0 part per million) in urban atmospheres over singel-pass optical path lengths ranging from 0.4 to 3 kilometers; spectral resolution capability of at least 1.0 cm^{-1} wave number at 1000 cm^{-1} and of at least 4 cm^{-1} cm wave number at 2000 cm^{-1}; wavelength scanning for at least the wavelength bands from about 3.0 to 5.0 microns and from 7.0 to 14.0 microns; spectral response displayed in terms of a linear frequency scale; scan rate time adjustable down to at least 2 minutes for any one band and a capability to cover the entire wavelength band of operation from 3.0 to 14.0 microns within a minimum time compatible with the specified resolution; ruggedness for field operation with portability and system stability to allow for mobile activity in relocation and transportation and accompanying shock and vibrations; maintenance of optical alignment, electric stability, and system calibration under conditions of field operation; a signal-to-noise ratio, at minimum concentration temperature radiance, of 2:1 for both the absorption and emission modes of operation; and display of output data both in analog forms on a recorder and in digital print-out.

The following additions criteria shall be met:

(1) Physical dimensions:

a. to permit transport indoors, outdoors, and onto rooftop by 2 men

b. to include mirrors $\leq$ 24 inches in diameter

(2) Delta S/N optimized for gas with absorption of 50% in 2 kilometer path, line width (half-power, full width, infinite resolution) of 0.1 cm^{-1} and Lorentz shape. Delta S/N should be equal to or greater than 10 through both bands.

(3) Resolution of 0.01μ in still atmosphere.

(4) Image dancing fluctuations in a 2 mile path of no more than 50% should occur when the light beam is deflected by 190 arc-seconds.

(5) If cooling is necessary for source, it should be a closed system.

(6) No handling of fluids or gases should be required for the detectors selected.

(7) Strip chart recorder should be compatible with fast scan speed of spectrometer.

(8) Digital printout should be capable of speed of 5 lines/sec. and of handling three parameters, i.e., wavenumber (5 digits), I and Io (3 digits each).

(9) Magnetic tape recording shall be provided with selection of 4 sampling rates: 0.1, 0.2, 0.5 and 1.0 cm^{-1} or 0.1, 0.2, 0.4 and 0.8 cm

(10) Measure of Io at source should be provided and this information transmitted for recording at detector location by direct telephone link or other acceptable means for reference and calibration purposes.

B. Reports

1. Monthly Progress Reports

During the period of performance of this contract the Contractor shall submit five copies of monthly progress reports to the Project Officer and one (1) copy to the Contracting Officer. The report shall be submitted within fifteen days of the month succeeding the month covered. This report shall be of brief narrative type and shall include the following:

a. A brief statement of work accomplished prior to the start of the current reporting period.

b. A brief statement of work performed during the reporting period, regardless of results, including photographs or charts necessary.

c. Any technical problems, schedules changes, etc., that will assist the Project Officer in evaluating the Contractor's progress.

d. A statement of work to be accomplished in the next reporting period.

e. Status of funds expended for the month and cumulative and including a graph comparing projected and actual costs.

2. Final Reports

a. The Contractor shall submit to the Project Officer for review, three draft copies of the final report within fifteen calendar days after the completion of the work called for under this contract. The report shall document in detail all of the work performed under the contract including data, analyses, and interpretations as well as recommendations and conclusions based upon the results obtained. The report shall include tables, diagrams, curves, photos, and drawings in sufficient detail to comprehensively explain the results obtained.

b. The Government shall review and return the draft copy with any comments within fifteen days of receipt of the draft.

c. Within thirty calendar days after receipt of the approved draft copy of the final report, the Contractor shall submit to the Project Officer fifteen copies including a reproducible master of the final report. One copy shall be furnished to the Contracting Officer.

d. The Contractor shall provide an instruction manual in five copies upon delivery of the equipment.

3.2 SYSTEM DESCRIPTION

The system can best be described by reference to the block diagram, Figure 3.2.1. Each enclosure is indicated by the dashed lines around the components within that enclosure. Optical paths are indicated by dotted lines.

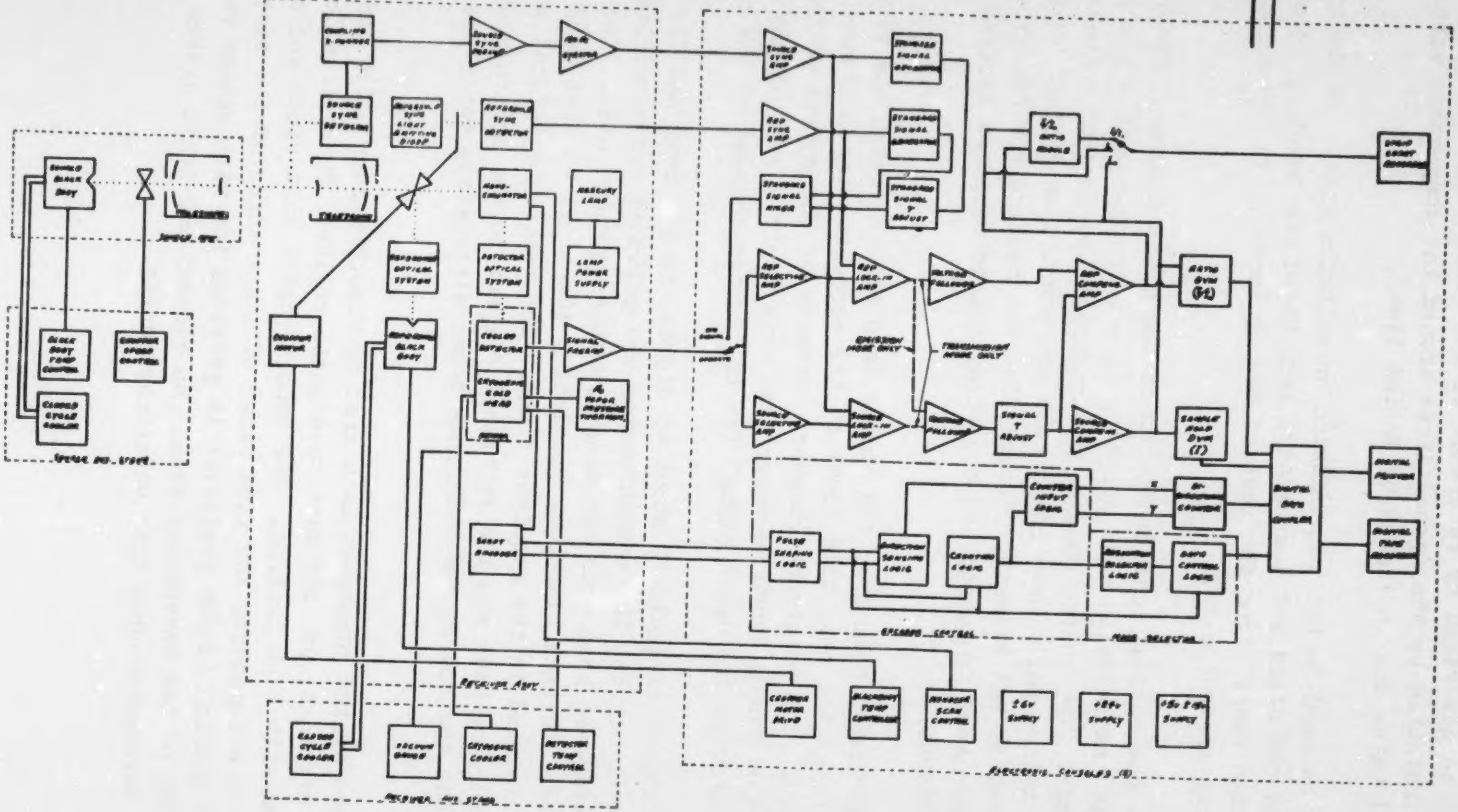
The system can be used in the transmission or emission mode. In the transmission mode the Source Stand and Source Auxiliary Stand are remotely located (0.4 to 4.0 km design range) from the rest of the equipment. In the emission mode these two units are not used.

Consider first the optical path indicated on the block diagram. The remote source used for the transmission mode consists of a telescope with a blackbody mounted at its focus. The source modulator (or chopper) is located between the blackbody and the telescope. These components are mounted on a stand which is adjustable in elevation and azimuth. Accessories for cooling the blackbody, controlling the modulator frequency and blackbody temperature are located in the Source Auxiliary Stand.

The nearly collimated beam from the source is directed toward the receiver telescope which brings the beam to a focus at the monochromator entrance slit after passing through the reference chopper. Because of the spread of the beam from the source, the Source Synch Receiver also intercepts a part of the beam which is used to provide the synch signal for the source channel of the electronics.

The receiver chopper is inclined about 45 degrees to the beam and the sides of the chopper teeth nearest the monochromator are polished and aluminized so as to reflect the reference beam onto the monochromator entrance slit. The reference beam starts at the reference blackbody (nominally identical to that used for the source) which is located in the receiver stand. The reference optical system transmits the reference beam via the reference chopper to the monochromator entrance slit so that the source and reference beams alternately enter the monochromator.

The dispersive system component is a grating monochromator which has two interchangeable gratings, one for each wavelength region. There is a long pass filter associated with each grating. The monochromator slit width and height are both adjustable to accommodate the wide range of image sizes of the system. Scanning of each grating ($d\nu/dt$ positive) is provided for with speeds ranging from 3/32 to 6 RPM of the wavenumber drum. An encoder and logic system convert rotation of the wavenumber drum into wavenumber units.



UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES √
RIVET BASIC CODE-NAS523

SEE 0-70814 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70002 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT BASE NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
.X ±.1 .XX ±.03 .XXX ±.010
ANGULAR PER 0-70002

SECURITY CLASSIFICATION

CHECK
STRESS
DRAWN E. Rollins

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

SYSTEM BLOCK DIAGRAM

Figure 3.2.1

D 14170 596-722-021

SCALE — SHEET 1 OF 1

After passing through the monochromator the beam goes to the detector via the detector optical system which forms a reduced image of the monochromator exit slit on the detector.

The receiver telescope, reference optical system, monochromator, detector optics and detector are mounted on a stand similar to that used at the source. This stand is also adjustable for elevation and azimuth.

The electrical signal from the detector has frequency components at the reference and source chopping frequencies as well as dc and sum and difference frequencies. These latter components are rejected by the selective amplifiers and the components at the source and reference frequencies pass to the lock-in amplifiers.

The source synch signal is obtained from the detector in the source synch receiver via a preamplifier. The reference synch signal is obtained from a photodiode which is actuated by reference chopper modulation of the beam from a light emitting diode.

Since the source beam is chopped by both choppers there is a source dependent component at the reference chopper frequency which must be eliminated. This is accomplished by blocking the reference beam in an initial balancing procedure and adjusting the gain of the reference channel so that the output of the reference compensation amplifier is zero. Upon removal of the block of the reference channel the output of the reference compensation amplifier is dependent only on the reference beam.

The output of the source compensation amplifier is called the I signal and the output of the reference compensation amplifier is called the I_o signal. Provision is made for adjusting the ratio I/I_o by means of the Signal τ Adjust potentiometer.

The I and I/I_o signals are digitized and displayed by digital voltmeters. The wavenumber is displayed by a bidirectional counter. Each of these three digital signals are fed to a digital recording system which permits paper tape printout and/or magnetic tape records to be made.

A strip chart recorder is also provided by means of which I, I_o or I/I_o can be recorded in analog form.

In the emission mode the reference blackbody is run at reduced temperature (ambient temperature in most cases) and only the reference channel is used.

A photograph of the source stand assembly is shown on Figure 3.2.2. The blackbody is located at the focus of the source telescope.

Photographs of the receiver stand assembly are shown on Figures 3.2.3 and 3.2.4. The monochromator entrance slits are mounted at the receiver telescope focus. The detector optics housing attached to the monochromator supports the dewar in which the detector is located. The detector cooler is mounted on top of the dewar and has a cold finger which extends down through the dewar. The detector is mounted on the bottom end of this cold finger.

A photograph of the electronic enclosures is shown on Figure 3.2.5. For identification of the electronic components refer to drawing no. 596-722-020, and Figures 3.2.6 through 3.2.9.

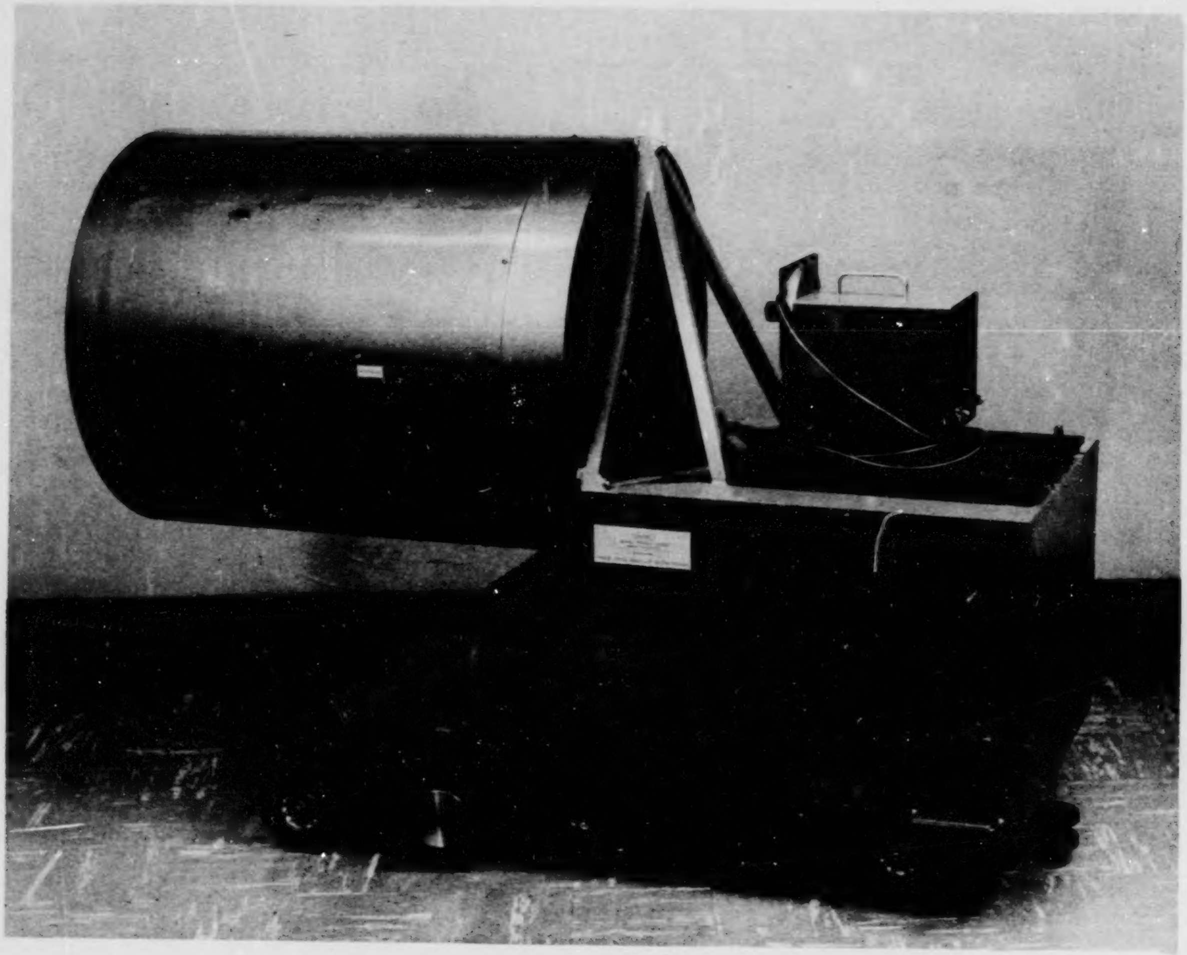


Figure 3.2.2 Photo: Source Stand

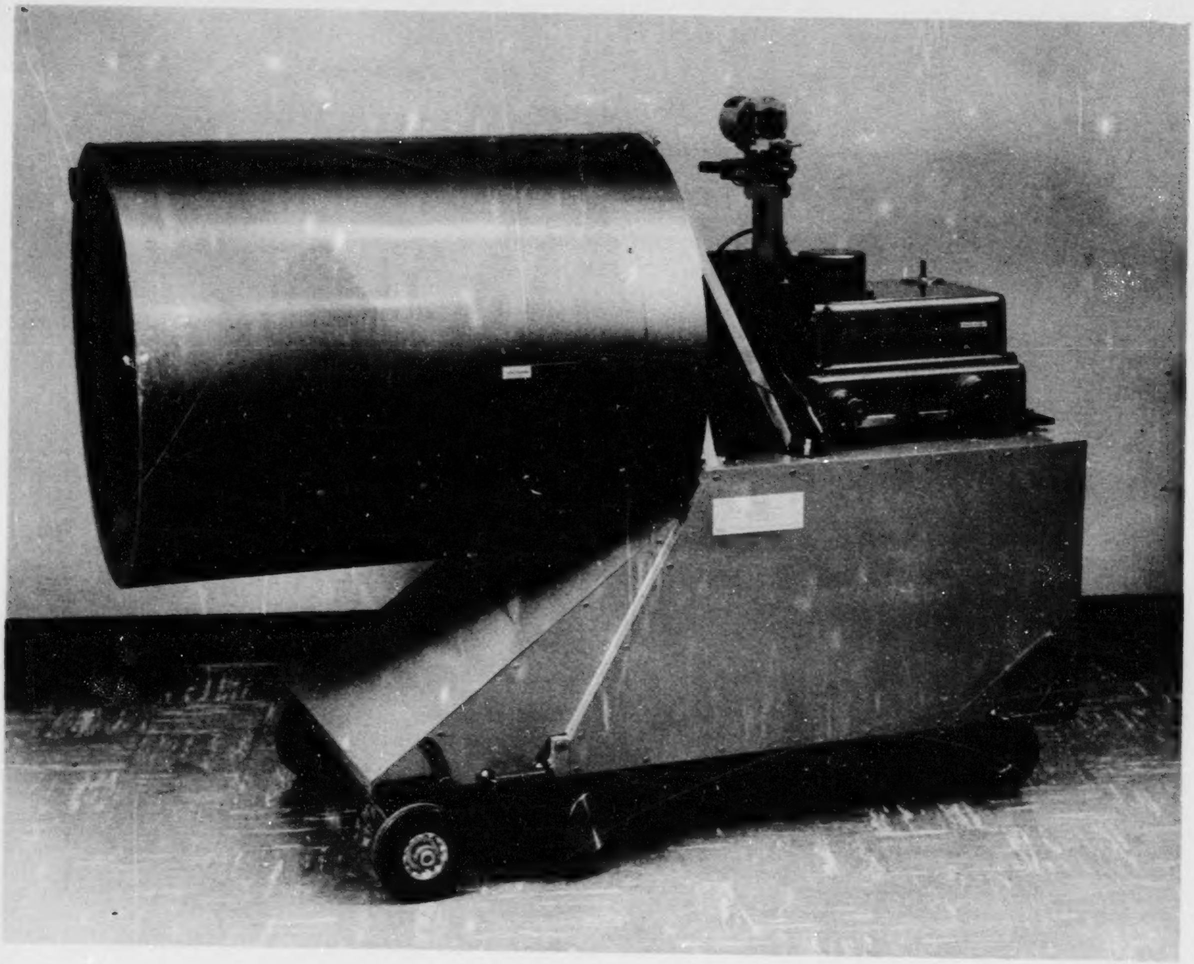


Figure 3.2.3 Photo: Receiver Stand - Left Side

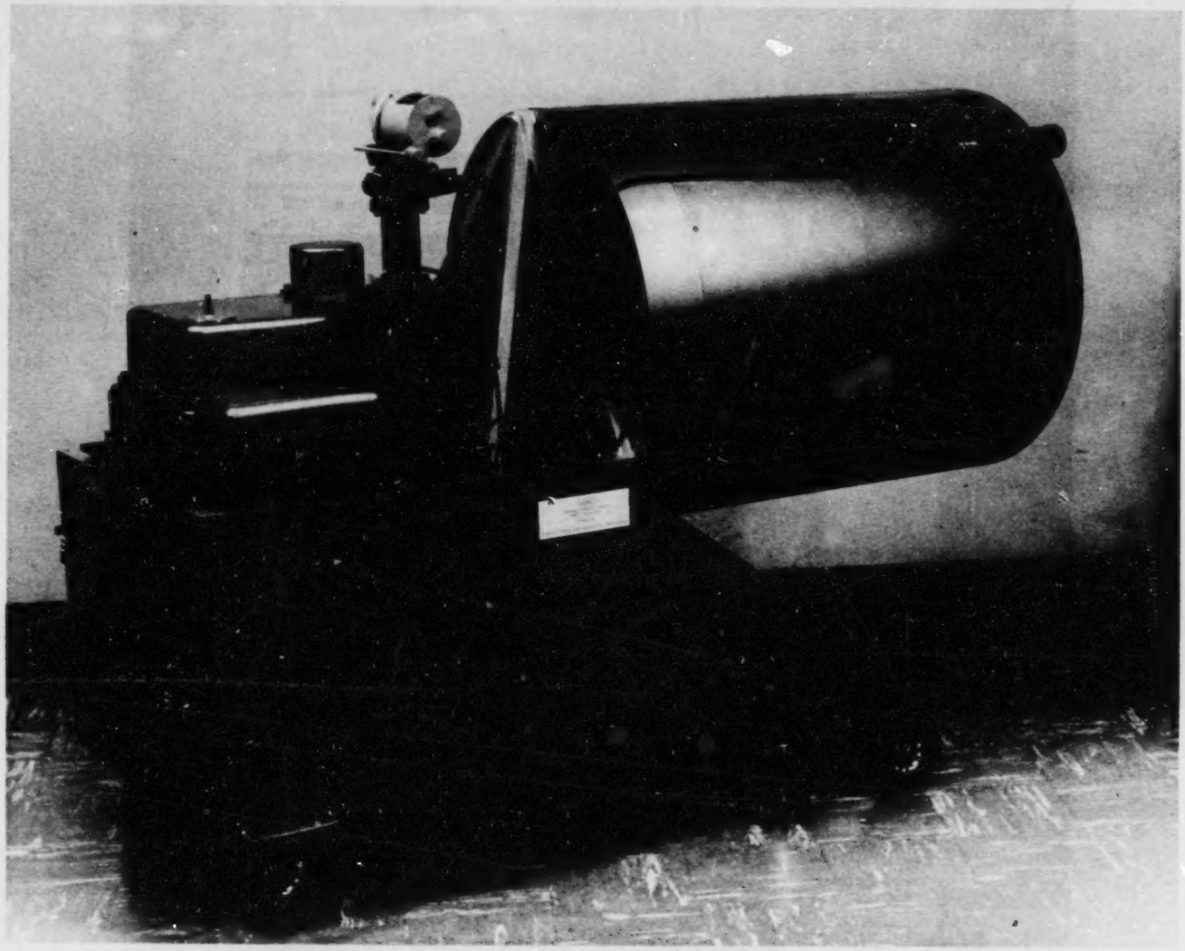


Figure 3.2.4 Photo: Receiver Stand - Right Side

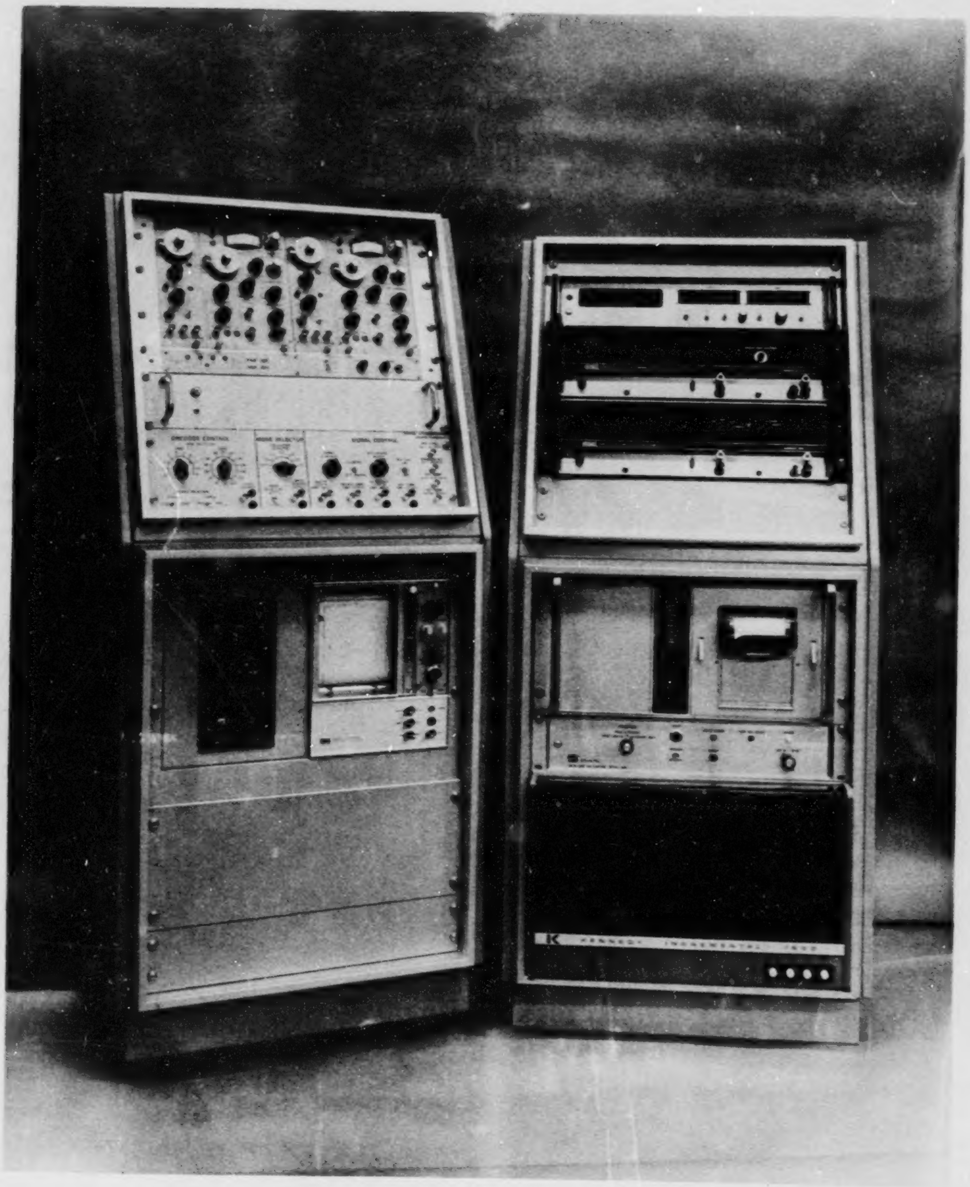


Figure 3.2.5 Photo: Electronic Consoles

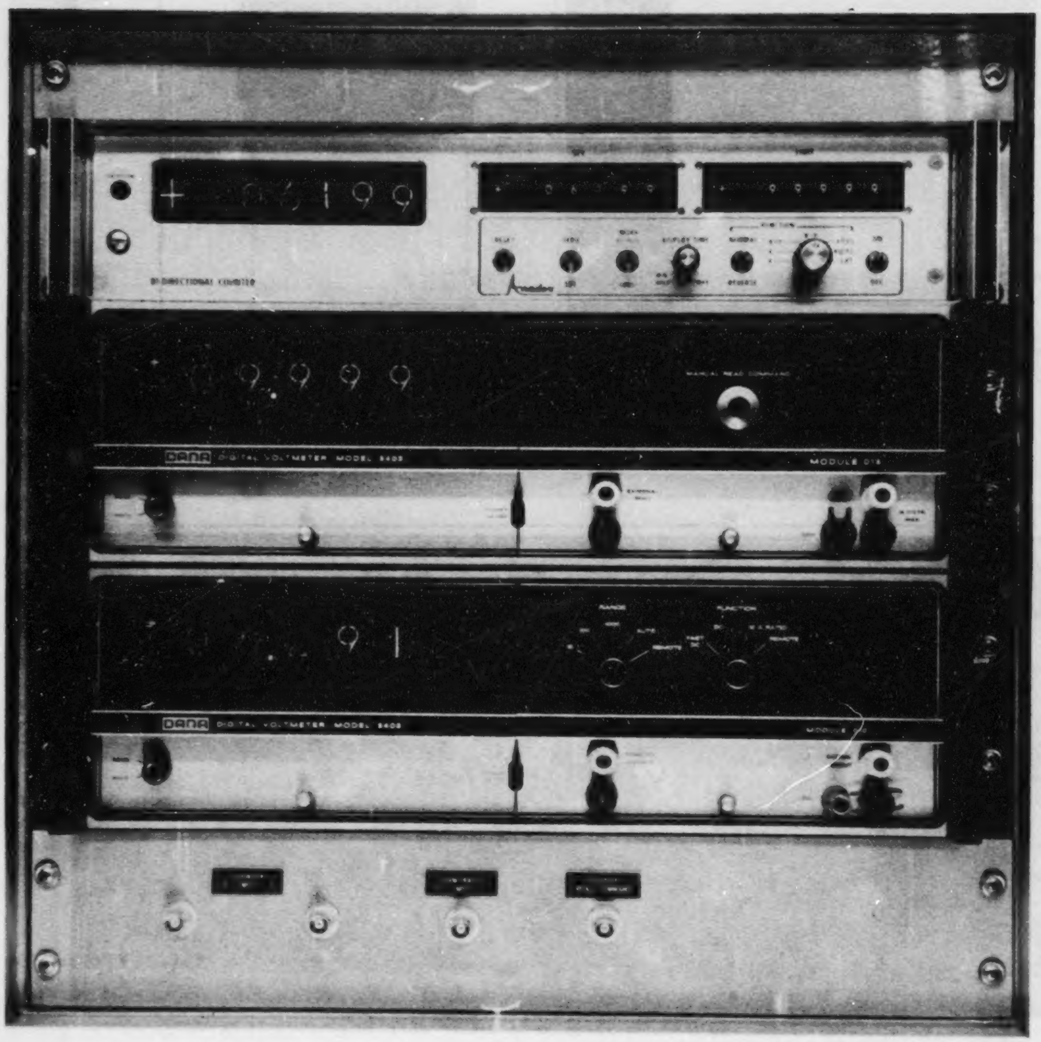

BI-DIRECTIONAL COUNTER
MANUAL READ COMMAND
DANA DIGITAL VOLTMETER MODEL 5403
DANA DIGITAL VOLTMETER MODEL 5403
RANGE
FUNCTION
REMOTE

Figure 3.2.6 Photo: Counter and DVM's

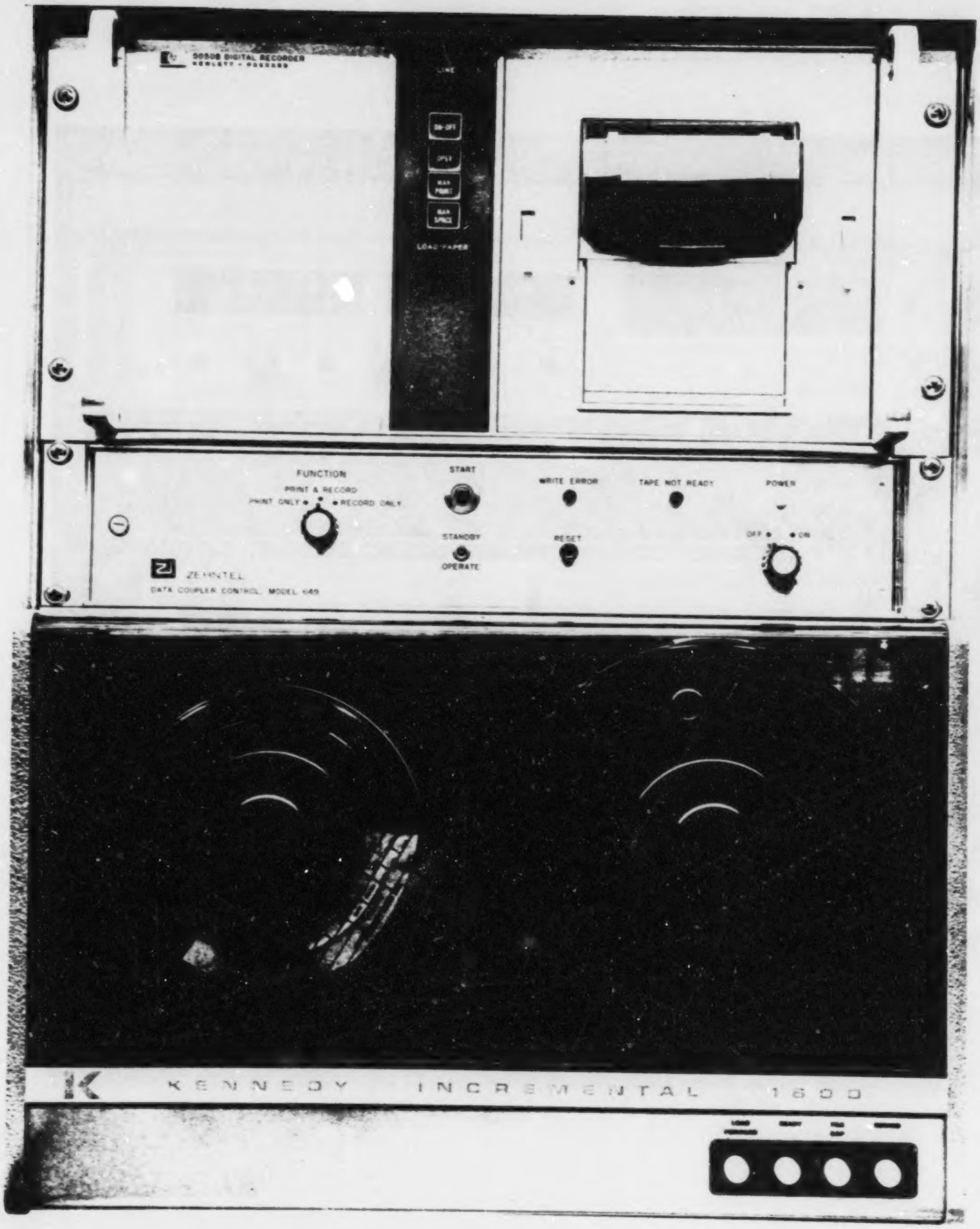


Figure 3.2.7 Photo: Digital Recorders

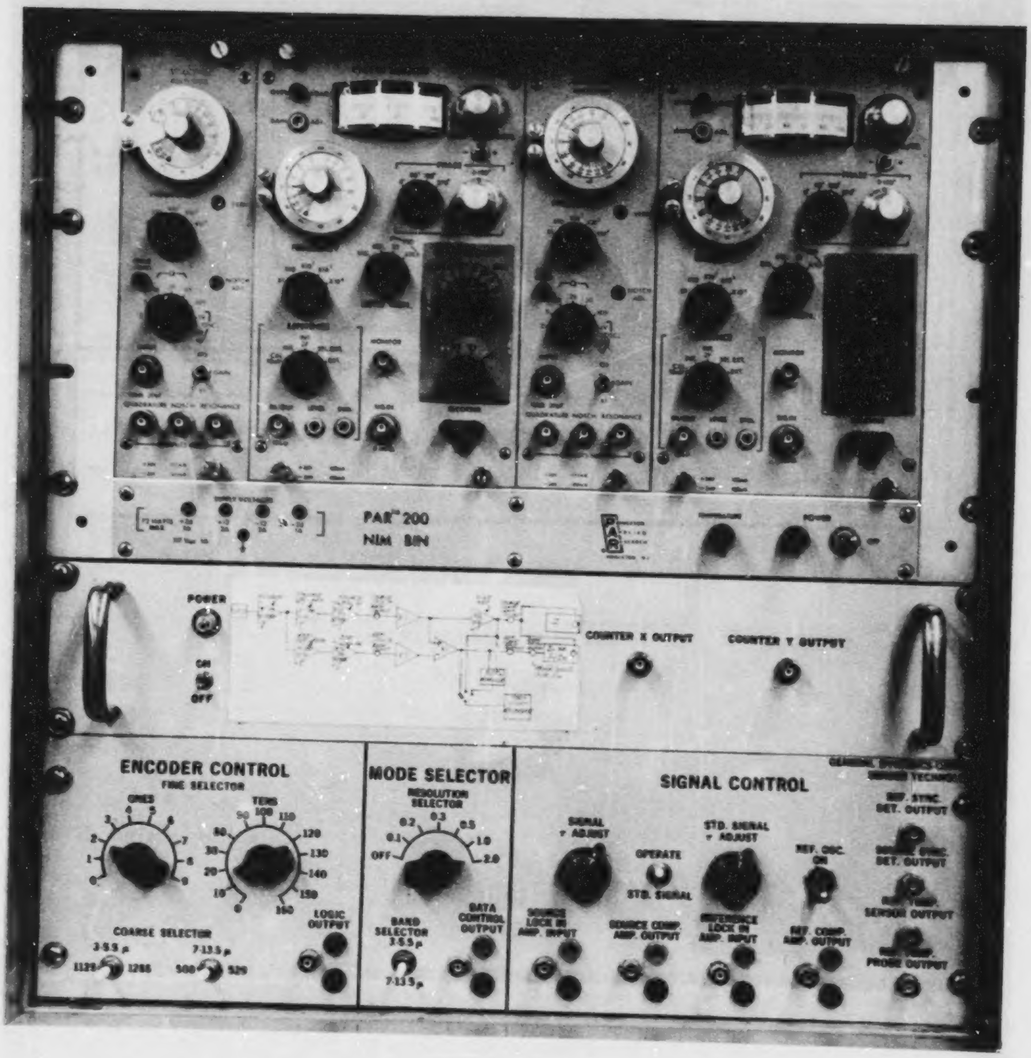


Figure 3.2.8 Photo: Data Processor and Control

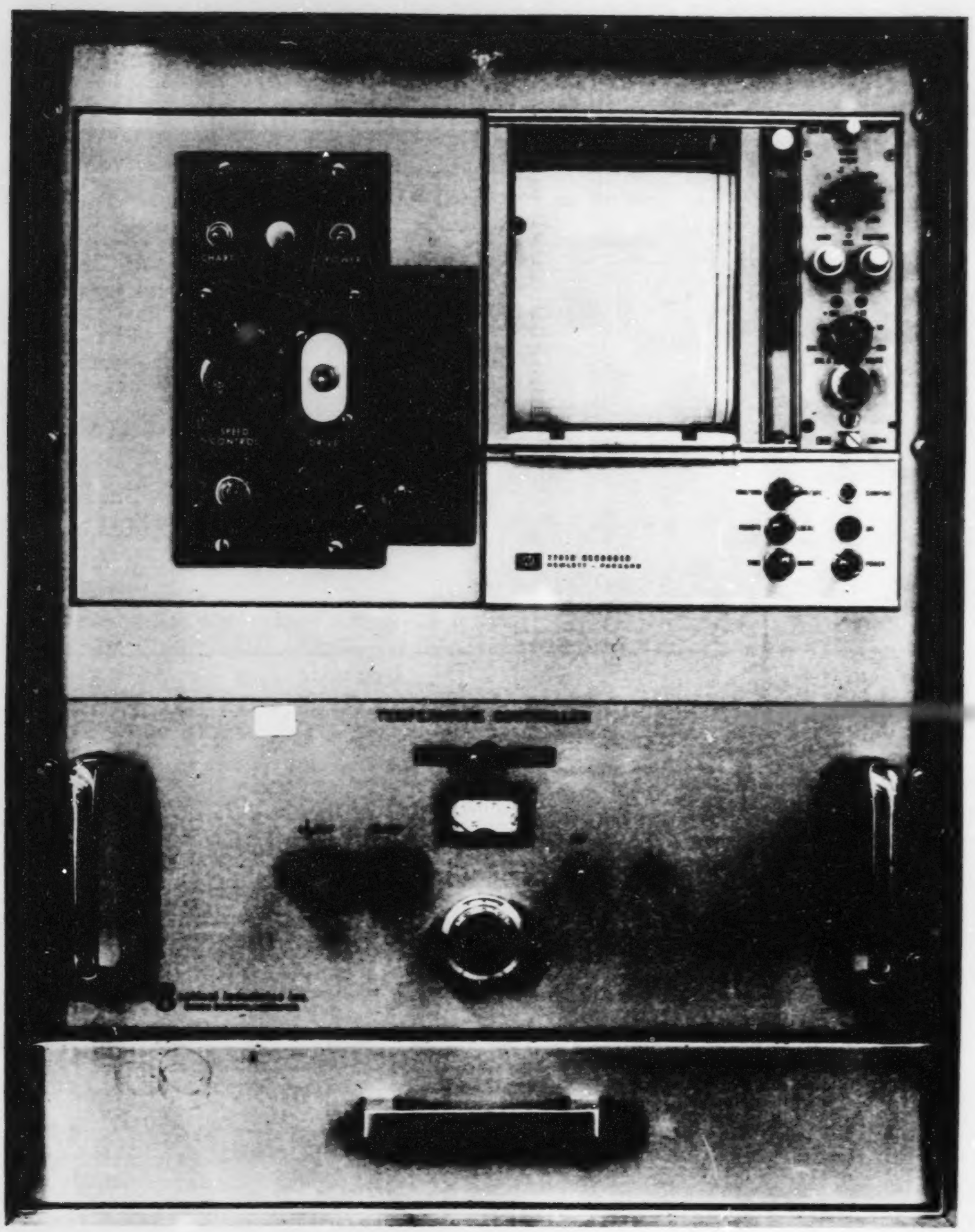


Figure 3.2.9 Photo: Analog Recorder - Temp. Control

3.3 RADIOMETRY

3.3.1 Signal Equations

This system design section on radiometry is concerned with identifying and estimating the values of parameters which affect the signal levels. In either the transmission or emission modes of operation the reference chopper in front of the monochromator alternately samples the beam from the receiver telescope and the beam from the reference optical system. For convenience these beams are called the source beam and the reference beam respectively. The source beam in the transmission mode of operation is modulated at the source blackbody in order to allow the electronics to separate the source and reference signals so that their ratio may be obtained. In the emission mode of operation the signal output results from the difference between the source and reference beams.

In each beam the flux is controlled by many parameters which includes the radiance of the source of energy, the geometrical optical properties or etendue, the transmission of windows, mirrors, etc., the spectral bandwidth and the appropriate modulation factors. Those portions of each beam upstream of the reference chopper are separate and those portions downstream of the reference chopper are common to both beams. Insofar as possible controlling parameters are placed in that portion of the system in which the beams have a common path and those parameters which cannot be located in the common path are made as nearly identical as possible.

Emission Mode of Operation

In the emission mode of operation there will be a net effective radiance $N_S(\lambda)$ at the system entrance pupil. This radiance is a complex function of background radiance, radiance of the object of interest, radiance of the gas between the object and the telescope, size and range of the object and spectral properties of the gases (and particulate matter, if present). The evaluation of this radiance is treated in detail in the field test report. For instrumental purposes it is sufficient to write the expression for the signal in terms of this effective source radiance.

The effective source radiance is actually an average taken over the spectral slit width of the system, $\Delta\lambda$,

$$N_s(\lambda)\,\Delta\lambda = \int_{\lambda}^{\lambda+\Delta\lambda} N_s'(\lambda)\,d\lambda$$

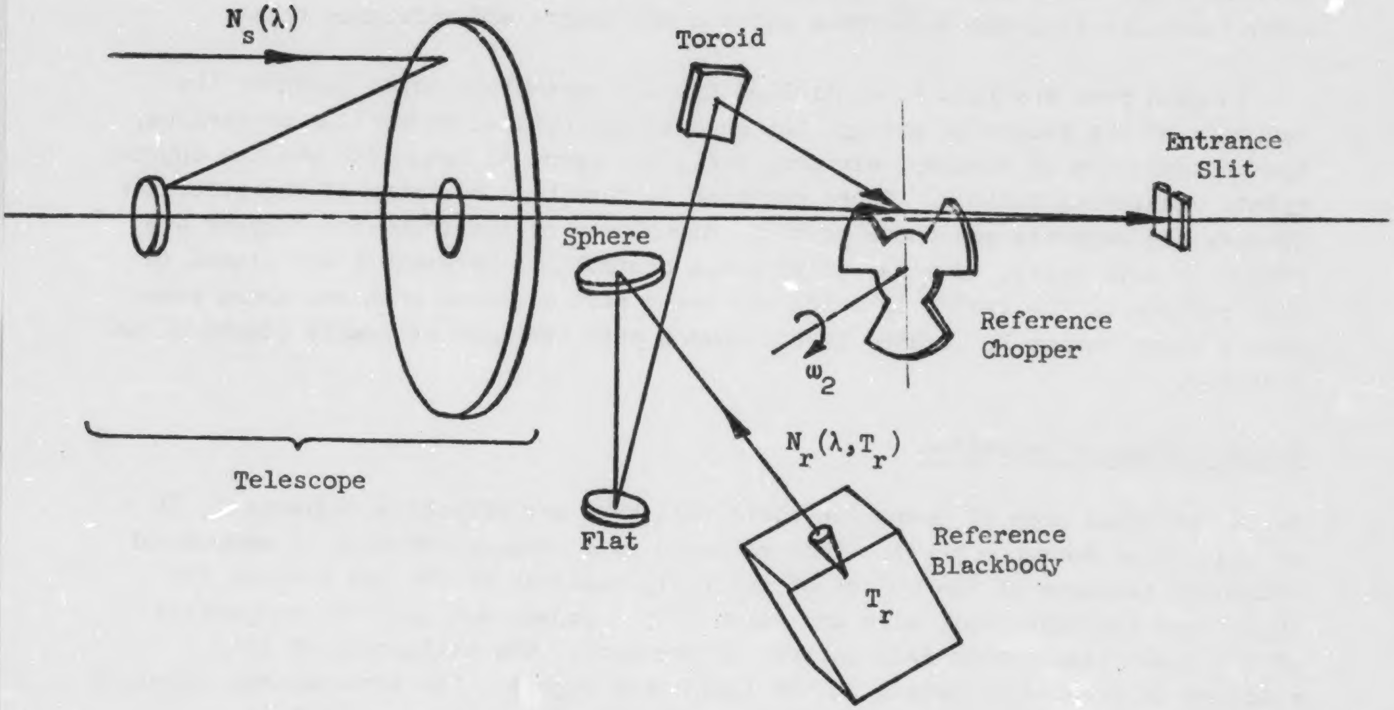


Figure 3.3.1.1 Emission Mode of Operation Schematic Optical Diagram

The effective source radiance, after two mirror reflections, passes through the reference chopper towards the monochromator entrance slit. The reference blackbody radiance after four mirror reflections (including the chopper) also passes to the entrance slit with 180° phase shift relative to the source beam (see Figure 3.3.1.1).

The amplitude of the power variation at the detector may be written:

$$
\begin{aligned}
P_d = {} & \tau_c A \Omega_c \Delta\lambda \Big[N_s(\lambda)(\rho)^2/2 + N_s(\lambda)(\rho)^2 M_2 \cos(\omega_2 t) + \dots \\
& + N_r^o(\lambda, T_r)(\rho)^4/2 + N_r^o(\lambda, T_r)(\rho)^4 M_2 \cos(\omega_2 t + \pi) + \dots \Big] \\
= {} & \tau_c A \Omega_c \Delta\lambda \Big[N_s(\lambda)(\rho)^2/2 + N_s(\lambda)(\rho)^2 M_2 \cos(\omega_2 t) + \dots \\
& + N_r^o(\lambda, T_r)(\rho)^4/2 - N_r^o(\lambda, T_r)(\rho)^4 M_2 \cos(\omega_2 t) + \dots \Big] \\
= {} & \tau_c A \Omega_c \Delta\lambda \Bigg[\frac{N_s(\lambda)(\rho)^2 + N_r^o(\lambda, T_r)(\rho)^4}{2} \\
& + \Big[N_s(\lambda, T_s)(\rho)^2 - N_r^o(\lambda, T_r)(\rho)^4 \Big] M_2 \quad \cos(\omega_2 t) + \dots \Bigg]
\end{aligned}
$$

where P_d = power at the detector - watts

M_2 = reference chopper modulation factor (peak to peak fund./2)/peak to peak wave

τ_c = common path system transmission

$A\Omega_c$ = common path etendue - cm^2 steradian

$\Delta\lambda$ = system spectral bandwidth - microns

$N_s(\lambda)$ = effective source radiance watts/cm^2 steradian micron

$N_r^o(\lambda,T_r)$ = reference blackbody radiance watts/cm^2 steradian micron

ρ = aluminum reflectance - one surface

ω_2 = reference chopper angular frequence - rad/sec

t = time-sec

Notice that there are essentially two terms: one at the reference chopper fundamental frequency and the other a d.c. term which is not sensed by the electronics since it is a.c. coupled. Signal components at other frequencies are not sensed by the electronics because of the tuned selective amplifier; the factor M_2 is the ratio of the pp amplitude/2 at the fundamental frequency to the peak to peak amplitude of the total power, i.e., the fundamental Fourier coefficient.

The flow of power is written relative to a cold black detector having negligible emission.

The peak to peak power of the fundamental component at the detector is:

$$P_d\ (pp) = 2\tau_c A\Omega_c \Delta\lambda \left[N_s(\lambda,T_s)(\rho)^2 - N_r^o(\lambda,T_r)(\rho)^4 \right] M_2$$

and the RMS power of the fundamental component at the detector is

$$P_d\ (RMS) = P_d\ (PP) \left(\frac{1}{2\sqrt{2}}\right)$$

The RMS voltage of the fundamental component at the detector is

$$S_d\ (RMS) = R_d\ \ P_d\ (RMS)$$

$$= R_d \frac{1}{\sqrt{2}}\ \tau_c\ A\Omega_c \Delta\lambda \left[N_s(\lambda,T_s)(\rho)^2 - N_r{}^o\ (\lambda,T_r)(\rho)^4 \right] M_2$$

where R_d = detector responsivity - RMS volts/RMS watt

In this formulation the spectral variations of responsivity and system transmission are neglected because these are small over the system spectral bandwidth.

The factors $(\rho)^2$ and $(\rho)^4$ account for the different number of surfaces in each beam. Alternatively, $(\rho)^2$ could be factored out and included with τ_c; the remaining $(\rho)^2$ in the reference term could be either evaluated or combined with $N_r^o(\lambda,T_r)$ to define a radiance at a slightly lower temperature, T_r':

$$N_r^o(\lambda,T_r') = N_r^o(\lambda,T_r)(\rho)^2$$

The signal at the detector is amplified by the preamplifier, selectively filtered by the selective amplifier and synchronously rectified by the lock-in amplifier.

The reference channel lock-in amplifier output for the emission mode of operation is,

$$S_{xr} = S_d(\text{RMS})\, G_p\, G_{fr}\, G_{xr} \cos(\phi_d - \phi_{synch})$$

where G_p = preamplifier gain - volts/volt

G_{fr} = reference channel selective amplifier gain - volts/volt

G_{xr} = reference channel lock-in amplifier gain - d.c. volts/RMS volt

ϕ_d = phase angle of detector signal

ϕ_{synch} = phase angle of synch signal

It is assumed that the phase control of the reference channel lock-in amplifier is adjusted so that $\cos(\phi_d - \phi_{synch}) = 1.00$.

$$S_{xr} = S_d \text{ (RMS) } G_p G_{fr} G_{xr}$$

$$= S_d \text{ (RMS) } G$$

where G = total gain - d.c. volts/rms volt

$$S_{xr} = R_d \tau_c A\Omega_c \Delta\lambda \left[\frac{\left[N_s (\lambda, T_s)(\rho)^2 - N^{\circ} (\lambda, T_r)(\rho)^4 \right] M_2}{\sqrt{2}} \right] G_p G_{fr} G_{xr}$$

For the emission mode of operation, the reference lock-in amplifier is connected to the source compensation amplifier. The output of the source compensation amplifier is

$$S_{cs} = S_{xr} (8.00) \tau_{sig}$$

In the emission mode of operation, τ_{sig} is set equal to 125 (1000 full scale) so that

$$S_{cs} = S_{xr}.$$

Transmission Mode of Operation

In the transmission mode of operation the signals must be separated electronically because the reference chopper chops both the reference and source beams.

Referring to Figure 3.3.1.2 the source radiance is composed of alternate flux levels represented by the source blackbody radiance $N_s^o(\lambda,T_s)$ and the source modulator wheel radiance $N_w^o(\lambda,T_w)$ assumed to be black. As before, the value of $N_s(\lambda)$ is the integrated value over the spectral slit width. Before passing through the atmosphere $N_s(\lambda)$ may be expressed as follows:

$$\begin{aligned}
N_s(\lambda) &= \rho^2\Big[N_s^o(\lambda,T_s)/2 + N_s^o(\lambda,T_s)M_1 \cos(\omega_1 t) + \ldots \\
&\qquad + N_w^o(\lambda,T_w)/2 + N_w^o(\lambda,T_w)M_1 \cos(\omega_1 t + \pi) + \ldots\Big] \\
&= \rho^2\Big[N_s^o(\lambda,T_s)/2 + N_s^o(\lambda,T_s)M_1 \cos(\omega_1 t) + \ldots \\
&\qquad + N_w^o(\lambda,T_w)/2 - N_w^o(\lambda,T\ )M_1 \cos(\omega_1 t) + \ldots\Big] \\
&= \rho^2\Big[\frac{N_s^o(\lambda,T_s) + N_w^o(\lambda,T_w)}{2} + \\
&\qquad + \Big(N_s^o(\lambda,T_s) - N_w^o(\lambda,T_w)\Big)M_1 \cos(\omega_1 t) \ldots\Big]
\end{aligned}$$

where M_1 = source modulator modulation factor
(peak to peak fund./2)/peak to peak wave

Signal components at multiples of the fundamental frequency are neglected; they will be discussed later.

For now it is sufficient to note that the d.c. term must be retained (as well as the $\cos(\omega_1 t)$ term) since it is subsequently chopped by the reference chopper.

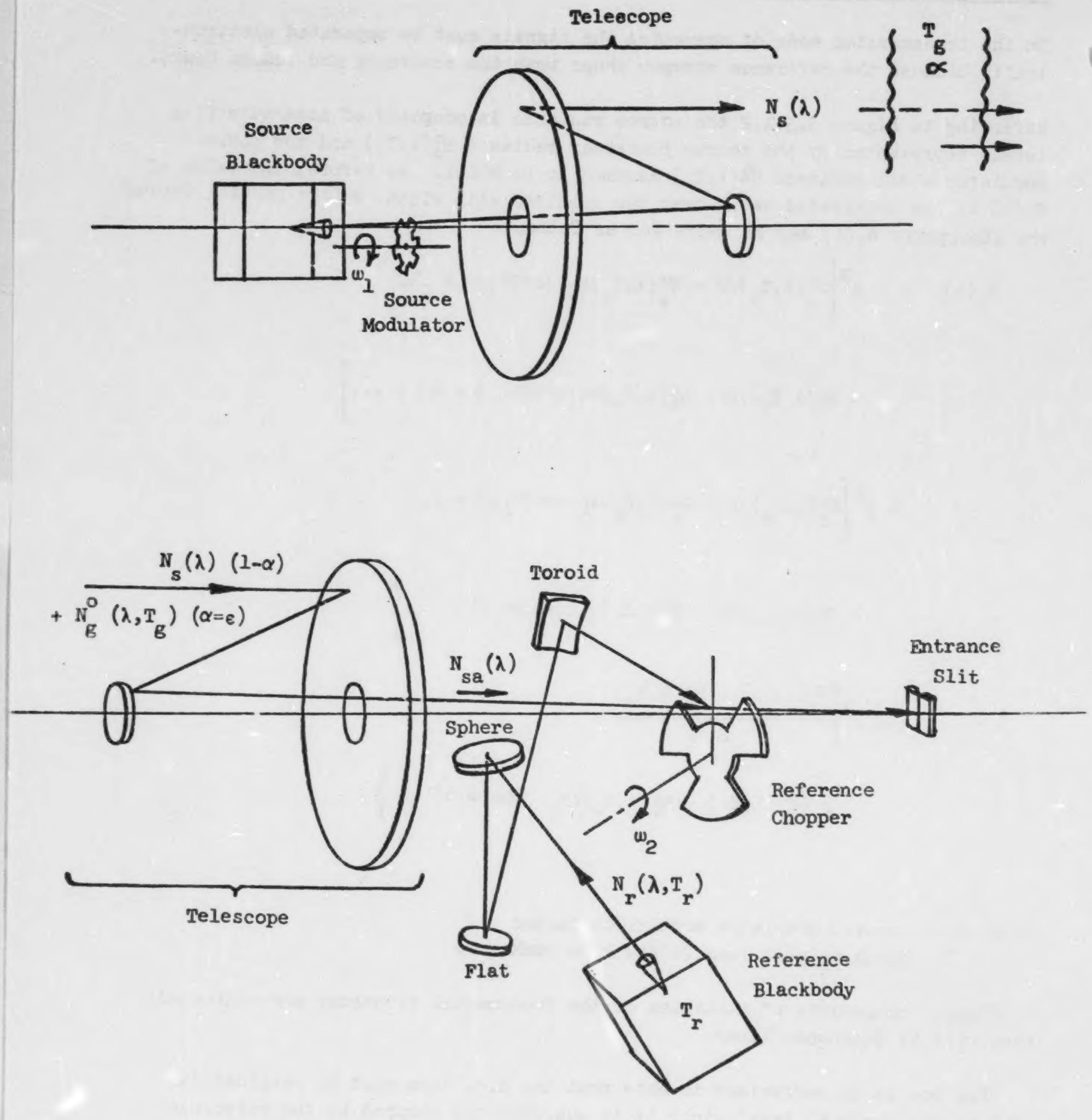


Figure 3.3.1.2 Transmission Mode of Operation Schematic Optical Diagram

The reference chopper combines the source and reference beams by alternately passing each one. The detector signal may be written as before except that, in this case, the source radiance has a time dependent term and is dependent on the transmission mode source beam etendue, $A\Omega_t$.

$$\text{Let } A = \frac{N^o_s(\lambda,T_s) + N^o_w(\lambda,T_w)}{2}$$

$$\text{and } B = \left(N^o_s(\lambda,T_s) - N^o_w(\lambda,T_w)\right)M_1$$

$$N_s(\lambda) = (\rho)^2 \left[A + B\cos(\omega_1 t) + \dots\right]$$

The source radiance is assumed to pass through an absorbing region having absorptivity, α, and temperature, T_g. The absorptivity of the reference path is neglected here since it is assumed that the transmission path is much longer than the reference path.

The source radiance after passing through the atmosphere and receiver telescope may be written as follows:

$$\begin{aligned} N_{sa}(\lambda) &= N_s(\lambda)(1-\alpha)\rho^2 + N_g{}^\circ(\lambda,T_g)(\alpha)(\rho)^2 \\ &= (\rho)^2 \left(A+B\cos(\omega,t)\right)(1-\alpha)(\rho)^2 \quad + N_g{}^\circ(\lambda,T_g)(\alpha)(\rho)^2 \end{aligned}$$

The source etendue, $A\Omega_t$, is less than the common etendue, $A\Omega_c$, which applies to all of the signal except that coming from the source. Therefore, the factor $(A\Omega_t/A\Omega_c)$ must be applied to the signal from the source.

The signal amplitude of the power variation at the detector for the transmission mode of operation may then be written:

$$P_d = \tau_c A\Omega_c \Delta\lambda \left\{ N_{sa}(\lambda)(A\Omega_t/A\Omega_c) + N_r{}^\circ(\lambda,T_r) + \left[(N_{sa}(\lambda)(A\Omega_t/A\Omega_c) - N_r{}^\circ(\lambda,T_r)\right] M_2 \cos(\omega_2 t) + \dots \right\}$$

$$P_d = \tau_c A\Omega_c \Delta\lambda \left\{ \left[\frac{((A + B\cos(\omega_1 t))(1-\alpha)(\rho)^4)(A\Omega_t/A\Omega_c)}{2} + \frac{N_g^o(\lambda,T_g)\alpha(\rho)^2}{2} + \frac{N_r^o(\lambda,T_r)(\rho)^4}{2} \right] \right.$$

$$\left. + \left[\left[(A + B\cos(\omega_1 t))(1-\alpha)(\rho)^4(A\Omega_t/A\Omega_c) + N_g^o(\lambda,T_g)\alpha(\rho)^2 - N_r^o(\lambda,T_r)(\rho)^4\right] M_2 \cos(\omega_2 t) \right] + \ldots \right\}$$

$$P_d = \tau_c A\Omega_c \Delta\lambda \left\{ \left[\frac{B(1-\alpha)(\rho)^4(A\Omega_t/A\Omega_c)M_2}{1.0} \right] \cos(\omega_1 t)\cos(\omega_2 t) + \left[\frac{B(1-\alpha)(\rho)^4(A\Omega_t/A\Omega_c)}{2} \right] \cos(\omega_1 t) \right.$$

$$+ \left[\frac{\left[A(1-\alpha)(\rho)^4(A\Omega_t/A\Omega_c) + N_g^o(\lambda,T_g)\alpha(\rho)^2 - N_r^o(\lambda,T_r)(\rho)^4\right] M_2}{1.0} \right] \cos(\omega_2 t)$$

$$\left. + \left[\frac{A(1-\alpha)(\rho)^4(A\Omega_t/A\Omega_c) + N_g^o(\lambda,T_g)\alpha(\rho)^2 + N_r^o(\lambda,T_r)(\rho)^4}{2} \right] + \ldots \right\}$$

The following trignometric identities are used in the subsequent analysis.

$$\begin{aligned}
\cos x \cos y &= \cos(x \pm y) \pm \sin x \sin y \\
&= \cos(x + y) + \sin x \sin y \\
&= \cos(x - y) - \sin x \sin y \\
2 \cos x \cos y &= \cos(x + y) + \cos(x - y) \\
\cos x \cos y &= \tfrac{1}{2} \cos(x + y) + \tfrac{1}{2} \cos(x - y)
\end{aligned}$$

Applying this result to the equation for P_d,

$$\begin{aligned}
P_d = \tau_c A\Omega_c \Delta\lambda \Bigg\{ & \left[\frac{B(1-\alpha)(\rho)^4 (A\Omega_t/A\Omega_c) M_2}{2}\right] \cos(\omega_1 + \omega_2)t \\
& + \left[\frac{B(1-\alpha)(\rho)^4 (A\Omega_t/A\Omega_c) M_2}{2}\right] \cos(\omega_1 - \omega_2)t \\
& + \left[\frac{B(1-\alpha)(\rho)^4 (A\Omega_t/A\Omega_c)}{2}\right] \cos(\omega_1 t) \\
& + \left[\frac{\left[A(1-\alpha)(\rho)^4 (A\Omega_t/A\Omega_c) + N_g^{o}(\lambda, T_g)\alpha(\rho)^2 - N_r^{o}(\lambda, T_r)(\rho)^4\right] M_2}{1.0}\right] \cos(\omega_2 t) \\
& + \left[\frac{A(1-\alpha)(\rho)^4 (A\Omega_t/A\Omega_c) + N_g^{o}(\lambda, T_g)\alpha(\rho)^2 + N_r^{o}(\lambda, T_r)(\rho)^4}{2}\right] + \ldots \Bigg\}
\end{aligned}$$

Because the selective amplifiers freely transmit only the tuned frequencies corresponding to ω_1 and ω_2, only the third and fourth terms are of interest here. The terms involving $(\omega_1 + \omega_2)$ and $(\omega_1 - \omega_2)$ are rejected by the selective amplifiers if these frequencies are far from the tuned frequencies and a.c. coupling blocks the d.c. term.

The peak to peak power of the fundamental components at the detector are as follows:

For the source (at ω_1):

$$P_d\,(PP) = 2\,\tau_c A\Omega_c \Delta\lambda \left[\frac{B(1-\alpha)(\rho)^4 (A\Omega t/A\Omega c)}{2}\right]$$

$$\text{with } P_d\,(RMS) = P_d(PP)\,\frac{1}{2\sqrt{2}}$$

$$\begin{aligned} S_d(RMS) &= R_d\, P_d\,(RMS) \\ &= R_d \tau_c A\Omega_c \Delta\lambda \left[\frac{B(1-\alpha)(\rho^4)(A\Omega t/A\Omega c)}{2\sqrt{2}}\right] \end{aligned}$$

For the reference (at ω_2):

$$S_d(RMS) = R_d \tau_c A\Omega_c \Delta\lambda \left\{\frac{A(1-\alpha)(\rho)^4 (A\Omega_t/A\Omega_c)\, M_2}{\sqrt{2}} + \frac{\left[N_g{}^\circ(\lambda,T_g)\alpha(\rho)^2 - N_r\,(\lambda,T_r)\rho^4\right] M_2}{\sqrt{2}}\right\}$$

If the ω_1 and ω_2 signal components of S_d are passed through their respective selective amplifiers and each synchronously rectified by their respective in-phase synch signals the signals at the two lock-in amplifier outputs will be:

For the source at (ω_1):

$$\begin{aligned} S_{xs} &= S_d(RMS) G_p\, G_{fs}\, G_{xs} \\ &= R_d \tau_c A\Omega_c \Delta\lambda \left\{\left[\frac{\left[N^o_s(\lambda,T_s) - N^o_w(\lambda,T_w)\right]\,(1-\alpha)(\rho)^4 (A\Omega_t/A\Omega_c) M_1}{2\sqrt{2}}\right] G_p\, G_{fs}\, G_s\right\} \end{aligned}$$

For the reference at(ω_2):

$$\begin{aligned} S_{xr} &= S_d(RMS) G_p\, G_{fr}\, G_{xr} \\ &= R_d \tau_c A\Omega_c \Delta\lambda \left\{\left[\frac{\left[N^o_s(\lambda,T_s) + N^o_w(\lambda,T_w)\right]\,(1-\alpha)(\rho)^4 (A\Omega_t/A\Omega_c) M_2}{2\sqrt{2}}\right.\right. \\ &\qquad \left.\left. + \frac{\left[N^o_g(\lambda,T_g)\alpha(\rho)^2 - N^o_r(\lambda,T_r)(\rho\cdot)^4\right] M_2}{\sqrt{2}}\right] G_p\, G_{fr}\, G_{xr}\right\} \end{aligned}$$

The source channel lock-in output, S_{xs}, is not a function of the reference radiance; the dominant radiance is the source radiance. The reference channel lock-in output, however, is "contaminated" by being a function of both the source and reference radiances.

The following procedure is used to "decontaminate" the reference signal.

With the reference beam blocked by a black surface at temperature, T_b, the lock-in outputs are summed in the (differential) reference compensation amplifier which has a gain of ± 1.00. The source signal goes to the non-inverting input and the reference signal goes to the inverting input. The output of the reference compensation amplifier is in this case

$$
\begin{aligned}
S'_{cr} &= S_{xs} - S'_{xr} \\
&= R_d \tau_c A\Omega_c \Delta\lambda \Bigg\{ \left[\frac{\left[N^o_s(\lambda, T_s) - N^o_w(\lambda, T_w) \right] (1-\alpha)(\rho)^4 (A\Omega_t / A\Omega_c) M_1}{2\sqrt{2}} \right] G_p \, G_{fs} \, G_{xs} \\
&\quad - \left[\frac{\left[N^o_s(\lambda, T_s) + (N^o_w \; \lambda, T_w) \right] (1-\alpha)(\rho)^4 (A\Omega_t / A\Omega_c) M_2}{2\sqrt{2}} \right. \\
&\quad \left. + \frac{\left[N^o_g(\lambda, T_g) \, \alpha(\rho)^2 - N^o_r(\lambda, T_b)(\rho)^2 \right] M_2}{\sqrt{2}} \right] G_p \, G_{fr} G_{xr} \Bigg\} \quad = 0
\end{aligned}
$$

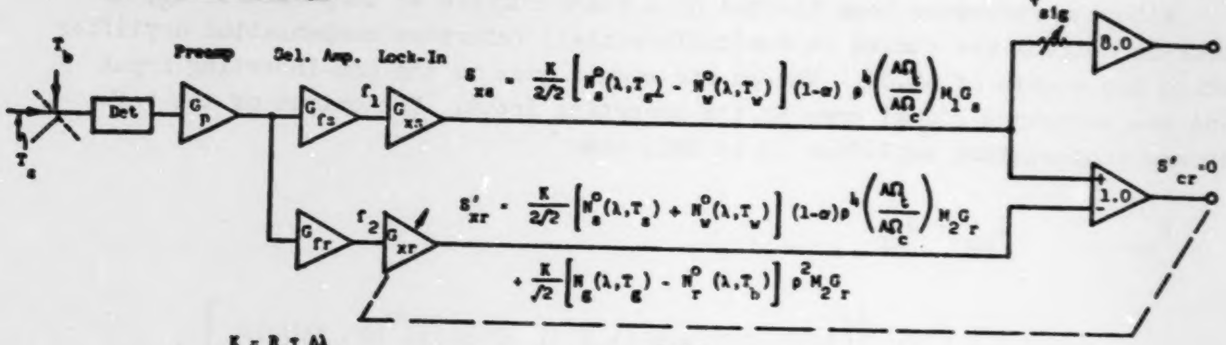
This signal is set equal to zero by small adjustment of the reference lock-in gain, G_{xr}, which is relatively independent of α or $(A\Omega_t / A\Omega_c)$.

With the reference beam block removed, the reference compensation amplifier output is identical to that for S'_{cr} except $N^o_r(\lambda, T_b)(\rho)^2$ is replaced by $N^o_r(\lambda, T_r)(\rho)^4$. Most of the terms are eliminated by the zero condition for S'_{cr} leaving:

$$
S_{cr} = R_d \tau_c A\Omega_c \Delta\lambda \left\{ \left[\frac{\left[N^o_r(\lambda, T_r)(\rho)^4 - N^o_r(\lambda, T_b)(\rho)^2 \right] M_2}{\sqrt{2}} \right] G_p \, G_{fr} G_{xr} \right\}
$$

The reference channel signal is now independent of the source radiance. Figure 3.3.1.3 shows the relations for S'_{cr} and S_{cr} which illustrate the method of "decontaminating" the reference signal.

Reference Balance



$$S_{xs} = \frac{K}{2\sqrt{2}}\left[N_s^0(\lambda,T_s) - N_w^0(\lambda,T_w)\right](1-\alpha)\,\rho^4\left(\frac{A\Omega_t}{A\Omega_c}\right)M_1G_s$$

$$S'_{xr} = \frac{K}{2\sqrt{2}}\left[N_s^0(\lambda,T_s) + N_w^0(\lambda,T_w)\right](1-\alpha)\rho^4\left(\frac{A\Omega_t}{A\Omega_c}\right)M_2G_r$$

$$+\frac{K}{\sqrt{2}}\left[N_g(\lambda,T_g) - N_r^0(\lambda,T_b)\right]\rho^2M_2G_r$$

$K = R_d\tau_c\Delta\lambda$

If $\rho = 1.0$

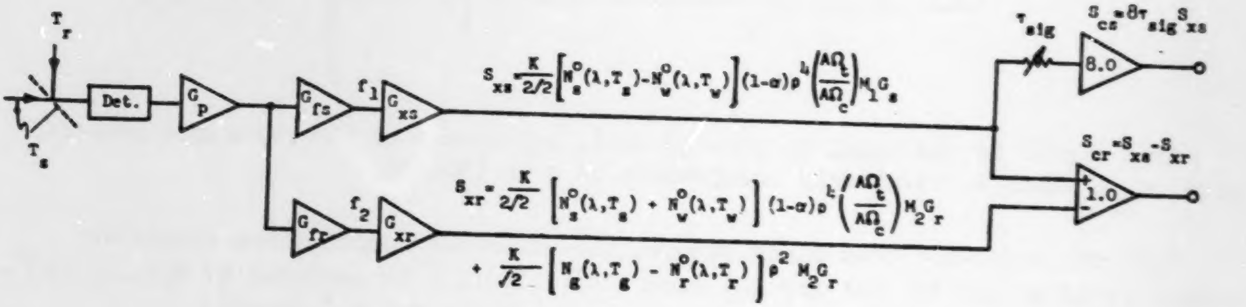
$G_r \sim G_s$

$$S_{xs} \sim \frac{K}{2\sqrt{2}}N_s^0(\lambda,T_s)\left(\frac{A\Omega_t}{A\Omega_c}\right)(1-\alpha)\,M_1G_s$$

$$S'_{xr} \sim \frac{K}{2\sqrt{2}}N_s^0(\lambda,T_s)\left(\frac{A\Omega_t}{A\Omega_c}\right)(1-\alpha)\,M_2G_r \sim S_{xs}$$

$$S'_{cr} = 0$$

Operation



$$S_{xs}=\frac{K}{2\sqrt{2}}\left[N_s^0(\lambda,T_s)-N_w^0(\lambda,T_w)\right](1-\alpha)\rho^4\left(\frac{A\Omega_t}{A\Omega_c}\right)M_1G_s$$

$$S_{xr}=\frac{K}{2\sqrt{2}}\left[N_s^0(\lambda,T_s)+N_w^0(\lambda,T_w)\right](1-\alpha)\rho^4\left(\frac{A\Omega_t}{A\Omega_c}\right)M_2G_r$$

$$+\frac{K}{\sqrt{2}}\left[N_g(\lambda,T_g)-N_r^0(\lambda,T_r)\right]\rho^2\,M_2G_r$$

If $\rho = 1.0$

$$S_{xs}\sim\frac{K}{2\sqrt{2}}N_s^0(\lambda,T_s)\left(\frac{A\Omega_t}{A\Omega_c}\right)(1-\alpha)M_1G_s$$

$$S_{xr}\sim\left[\frac{K}{2\sqrt{2}}N_s^0(\lambda,T_s)\left(\frac{A\Omega_t}{A\Omega_c}\right)(1-\alpha)\right]M_2G_r-\frac{K}{\sqrt{2}}N_r^0(\lambda,T_r)M_2G_r$$

$$S_{cs}\sim\frac{K}{2\sqrt{2}}N_s^0(\lambda,T_s)\left(\frac{A\Omega_t}{A\Omega_c}\right)(1-\alpha)\,M_1G_s\,8\tau_{sig}$$

If $\tau_{sig} = \frac{A\Omega_c}{A\Omega_t}\,\frac{1}{4}$

$$\sim\frac{K}{\sqrt{2}}N_s^0(\lambda,T_s)M_1G_s(1-\alpha)$$

$$S_{cr}\sim\frac{K}{\sqrt{2}}N_r^0(\lambda,T_r)M_2G_r$$

If $N_s^0 = N_r^0, M_1 = M_2$

$G_s \sim G_r$

$$\tau_{ind.} = S_{cs}/S_{cr} \sim (1-\alpha)$$

Figure 3.3.1.3 "Decontamination" Schematic

This fact may be verified experimentally by blocking the source beam ahead of the reference chopper and noting the negligible change in the reference compensation amplifier output.

The output of the source compensation amplifier depends on its gain (= 8.00) and the τ_{sig} potentiometer setting and equals

$$S_{cs} = S_{xs}\,(8.00)\tau_{sig}$$

$$= R_d \tau_c A\Omega_c \Delta\lambda \left\{ \left[\frac{\left[N^o_s(\lambda,T_s) - N^o_w(\lambda,T_w)\right] (1-\alpha)(\rho)^4 (A\Omega_t/A\Omega_c) M_1}{2/2} \right] \right.$$

$$\left. G_p \; G_{fs} \; G_{xs} \; (8.00)\tau_{sig} \right\}$$

The indicated transmission, $\tau_{ind.}$, is the ratio,

$$\tau_{ind.} = \frac{S_{cs}}{S_{cr}} = \left\{ \frac{\left[N^o_s(\lambda,T_s) - N^o_w(\lambda,T_w)\right] (1-\alpha)(A\Omega_t/A\Omega_c) M_1}{\left[N^o_r(\lambda,T_r) - N^o_r(\lambda,T_b)(1/\rho)^2\right] M_2} \right.$$

$$\left. \frac{G_p \; G_{fs} \; G_{xs} \; 4.00 \; \tau_{sig}}{G_p \; G_{fr} \; G_{xr}} \right\}$$

$N^o_s(\lambda,T_s) = N^o_r(\lambda,T_r)$ if $T_s = T_r$ and the source chopper blade temperature, T_w, is assumed to equal that of the reference block, T_b. The source chopper blade is polished on the side nearest the source to reduce chopper blade heating and is blackened on the side facing the telescope. The manufacturer estimates that the chopper blade is heated to less than 2 or 3°C above ambient. The temperature of the reference block should also be near ambient. Since the second term in the square bracket of both the numerator and denominator of the above equation are small compared to the first term (about 2% or less) small differences of the second term and the factor $(1/\rho)^2$ may be neglected.

The equation for the indicated transmission then becomes,

$$\tau_{ind.} = \left\{ \frac{(A\Omega_t/A\Omega_c) M_1 \, G_{fs} \, G_{xs} \, (4.00) \tau_{sig.}}{M_2 \, G_{fr} \, G_{xr}} \right\} (1-\alpha)$$

where $(1-\alpha)$ represents the true transmission.

The coefficient within brackets is constant for a given set-up and is adjustable by means of the $\tau_{sig.}$ control. Without knowledge of the terms within the bracket one may select a spectral region where α is known or negligible and set $\tau_{sig.}$ so that $\tau_{ind.}$ on the ratio D.V.M. equals $(1-\alpha) = \tau_{true}$ or 1.00 respectively.

It is of interest to consider the range of τ_{sig} setting required in order for τ_{ind} to equal $(1-\alpha)$. As shown in the next section $(A\Omega_t/A\Omega_c)$ can vary from 1.0 in the laboratory to about 0.25 at a range of 3 km with $h/h_o = 1.0$ and $S/h_o \sim 0.56$ (i.e. $s \sim 700$ microns). The factor (M_1/M_2) is approximately $0.63/0.58 = 1.08$. The gains G_{fs} and G_{xs} should be nearly equal to G_{fr} and G_{xr}, respectively. Therefore, if τ_{ind} is to equal $(1-\alpha)$, τ_{sig} must range from about 0.25 with negligible vignetting (e.g. in the laboratory) to about 1.00 at a range of 3 km with the given conditions.

The effect of harmonics and sum and difference frequencies has been neglected up to this point.

For complex waveforms there will be, in addition to the signals $\omega_1 = 2\pi f_1$ and $\omega_2 = 2\pi f_2$ used in the analysis, harmonics nf_1 and nf_2 which can interact to produce sum and difference frequencies nf_1-f_2, nf_1+f_2, nf_2-f_1, and nf_2+f_1.

Consider the following table which shows the various frequencies in the neighborhood of the tuned frequencies f_1=570 Hz and f_2=330 Hz.

n	nf_1	nf_1-f_2	nf_1+f_2	nf_2	nf_2-f_1	nf_2+f_1
1	570 Hz	240 Hz	900 Hz	330 Hz	-240 Hz	900 Hz
2	1140	810	1470	660	90	1230
3	1710	1380	2040	990	420	1560

Assuming equal radiances in both beams and no absorption or vignetting and square wave modulation, the relative rms signal strengths at the detector for the various harmonics are as follows (normalized to a unit reference frequency signal).

n	nf_1	nf_1-f_2	nf_1+f_2	nf_2	nf_2-f_1	nf_2-f_1
0(D.C.)				(2.36)		
1	1.00	0.64	0.64	1.00	-	-
2	0.33	0.21	0.21	0.33	0.21	0.21
3	0.20	0.13	0.13	0.20	0.13	0.13

The closest harmonic signal frequency component to f_2=330Hz is at (nf_1-f_2) = 240 Hz and $\Delta f/f$ equals 90/330 = 0.27. (The fifth harmonic of the line frequency is 300 Hz which gives $\Delta f/f$ = 30/330 = 0.091; the amplitude of this harmonic is much smaller than its fundamental, however). The closest harmonic signal frequency component to f_1 = 570 Hz is at (nf_2-f_1) = 420 Hz and $\Delta f/f$ = 150/570 = 0.26. Since this component is a harmonic, its amplitude should be well below (about 1/5) that of the 240 Hz component. Furthermore, it will be attenuated more by the time constant filter than the 240 Hz component. Consequently, only the 240 Hz component (and the 300 Hz line component) will be considered in the following analysis.

Let the 330 Hz signal be S_o and the 240 Hz interfering signal component be N_o. From the table it can be seen that the initial signal to noise ratio of S_o/N_o is about (1.0/0.64) = 1.6. The gain of the selective amplifier at 240 Hz is about 0.21 of the gain at the tuned frequency of 330 Hz. The signal to noise ratio downstream of the selective amplifier S_1/N_1 is therefore, (1.6/0.21) = 7.5. The desired signal S_1, at the lock-in amplifier input will produce a D.C. signal output $S_2 = G_x S_1$ if the synch signal is in phase with S_1, where G_x is the lock-in amplifier gain. The interfering signal, N_1, at the lock-in amplifier input will produce a varying signal $N_2 = G_xN_1 (\cos \phi_n-\phi_s)$ whose peak to peak amplitude equals $2\ G_xN_1$ and whose rms value is $2\ G_xN_1/(2/2) = G_xN_1/\sqrt{2}$. This signal after passing through the low pass RC time constant filter is modified so that the final lock-in amplifier DC signal to rms noise output is

$$\frac{S_3}{N_3} = \frac{S_2}{N_2}\left(1+\omega^2 \tau_x^2\right)^{\frac{1}{2}}$$

where $\omega = 2\pi(nf_1-f_2)$ = 90 Hz and τ_x is the time constant of the filter. Assuming a minimum time constant of 0.01 seconds.

$$\frac{S3}{N_3} = \frac{G_xS_1\sqrt{2}}{G_xN_1}\left[1+(2\pi\ 90)^2(10^{-4})\right]^{\frac{1}{2}} = 7.5\sqrt{2}\ (5.7) \sim 61$$

Thus, the rms noise components would be no more than 1.6% (approximately 4.7% peak to peak) of the desired D.C. signal even with this short time constant and would be roughly proportional to the time constant ratio $(0.01/\tau)$ for other time constants.

A similar analysis for the 300 Hz harmonic of the line frequency assuming $S_o/N_o \sim 40$ (measured after adding detector bias filter) gives $S_1/N_1 \sim 82$ and $S_3/N_3 = 82\sqrt{2}\,(2.16) = 250$ again for $\tau_x = 0.01$ sec. Thus the rms noise would be about 0.4% (about 1.1% peak to peak) of the desired D.C. signal.

3.3.2 Etendue

For radiometric purposes the geometrical optical property of either beam is variously known as the optical invariant, $A\Omega$, Lagrange invariant, throughput or etendue. It is determined by the apertures of the system and their location. If A_1 and A_2 are the areas of the apertures and R is the distance between them

$$A\Omega = A_1 A_2 / R^2$$

Alternatively, $A\Omega$ may be calculated from the areas of the corresponding pupils or windows and the distance between the pupils or windows.

In general, it is desirable to locate the apertures in that portion of the system common to both beams. This is done in the present system for the emission mode by making the monochromator entrance slit and grating mask the system apertures. The other optical elements are made large enough so that their boundaries do not limit the flux. The entrance slit area $A_1(s,h)$ varies with slit width, s, and slit height, h. The affective area (normal to the beam) of the grating mask $A_2(\theta)$ varies as the cosine of the grating angle, θ. The distance between the apertures is the monochromator collimator focal length (266 mm). In the emission mode of operation, then, for either the source or reference beams, the etendue is,

$$A\Omega_c = A_1(s,h)\, A_2'(\theta)/F_c^{\,2} = A_1(s,h)(A_2' \cos\theta)/F_c^{\,2}$$

where $A\Omega_c$ = common path etendue cm^2 steradian

s = slit width-mm

h = slit height-mm

A_2' = grating mask area-cm^2

θ = grating angle

F_c = collimator focal length-mm

The grating mask is imaged onto the receiver telescope primary mirror by the field lens (in front of the entrance slit) and the telescope secondary mirror. This image of the grating mask is the receiver system entrance pupil which is similar in shape to the effective grating mask and larger by the ratio of the telescope focal length to the monochromator collimator focal length. $A\Omega$ can be calculated from

$$\begin{aligned} A\Omega_c &= A_1(s,h)\, A_2'(\theta)/F_c^2 \qquad cm^2 \text{ steradian} \\ &= (s)\,(h)\, A_2' \cos\theta/F_c^2 \\ &= (s)\,(h)\, (A_2' \cos\theta)(F/F_c)^2/F^2 \\ &= (s)\,(h)\, (A_2 \cos\theta)/F^2 \end{aligned}$$

where F = receiver telescope focal length (= 3048 mm)

$A_2\cos\theta$ = entrance pupil area -cm^2

It was decided that for the emission mode of operation focussing the object on the entrance slit would require frequent tedious changing of the focus and, therefore, a fixed focus would be used.

The boundaries of the field in the emission mode are determined from the receiver entrance pupil (image of grating mask on receiver telescope primary mirror), the entrance slit size and the telescope focal length. For an infinitesimal slit width and height the field boundary is just the outline of the entrance pupil which is similar to the grating mask but (3048/266) times larger. For finite entrance slit sizes there is a divergence of the beam equal to the slit height or width divided by the telescope focal length times the range. The total field width or height is the sum of the entrance pupil width or height plus the beam divergence.

Maximum values of the field size are shown on Figure 3.3.2.1 for maximum slit height of 12 mm and maximum slit width of 2 mm. Also shown is the ½ degree specification value; the maximum field size is less than the specification value for ranges beyond about 150 meters. Values of the field size for the focussed condition are shown also for comparison. Note that the full primary mirror diameter is used for the maximum entrance pupil size.

In the transmission mode of operation reference beam the etendue is calculated exactly as it is for the emission mode of operation since the apertures are the entrance slit and grating mask as before. The components of the reference optical system are made large enough so as not to limit the reference beam.

The etendue for the transmission mode source beam is more complicated as a result of vignetting caused by the large values of range. One aperture of the system is the monochromator entrance slit and the other aperture is a composite of the entrance pupil of the receiver system (image of the grating mask, as before) and the exit pupil of the source system (which is just the net unobscured source primary mirror aperture). For an infinitesimal slit height and width the on-axis etendue for the transmission mode of operation is

$$\begin{aligned} dA\Omega &= dA_1(s,h)\, A_2(\theta)/F^2 \\ &= (ds)(dh)(A_2 \cos\theta)/F^2 \end{aligned}$$

where the terms are the same as those defined before for the emission mode of operation. For any off-axis point on the entrance slit, however, the flux is limited by the exit pupil of the source system. For a point at the entrance slit sufficiently far from the axis there will be no flux because the pupils do not overlap (see Figure 3.3.2.2). Consequently all the flux is contained within a maximum total height (or width) of

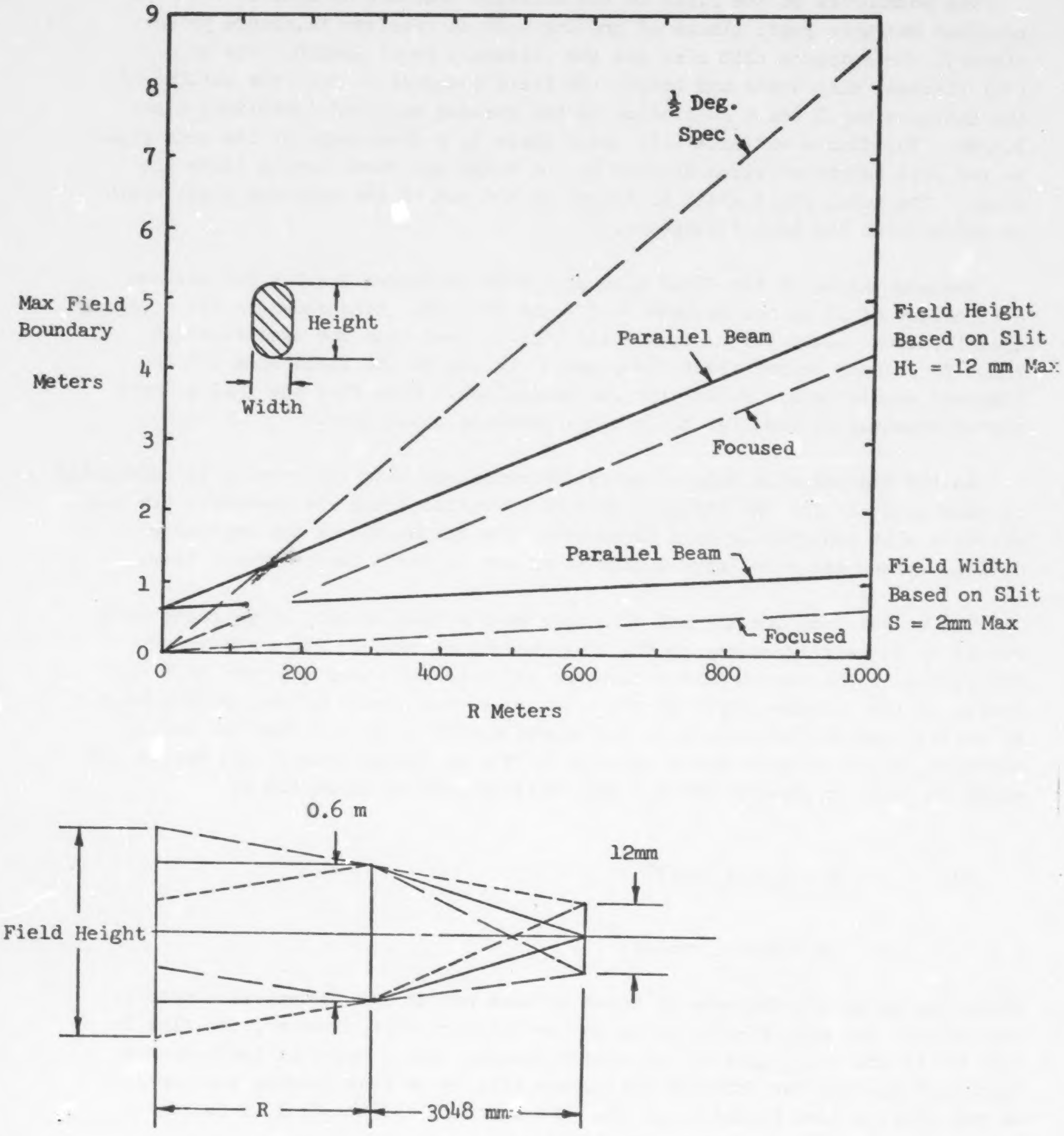
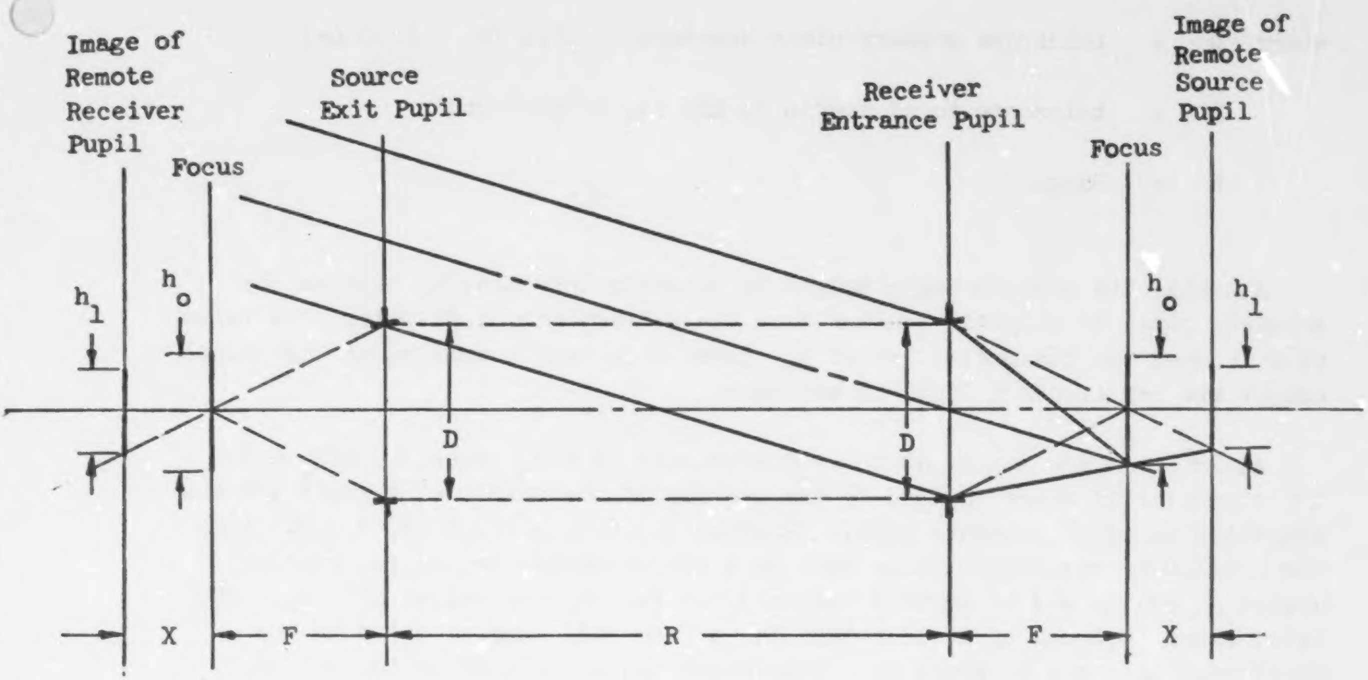


Figure 3.3.2.1 Emission Mode Field of View



$$\frac{h_o/2}{F} = \frac{D}{R} \qquad h_o = \frac{2DF}{R}$$

$$\frac{h_1/2}{X} = \frac{D/2}{F} \qquad h_1 = \frac{DX}{F}$$

$$X = \frac{F^2}{R-F} \qquad \therefore h_1 = \frac{DF}{R-F}$$

IF $R \gg F$

$$h_1 \cong h_o/2 \quad \text{and} \quad X \cong F^2/R$$

Figure 3.3.2.2 Transmission Mode Geometry

$$h_o = \frac{2DF}{R}$$

where D = telescope primary clear aperture (= 24.0 in. = 61.0 cm)

F = telescope focal length (= 120 in. = 304.8 cm)

R = Range

Actually the maximum image height is slightly less than h_o because the entrance pupil is slightly smaller than the primary mirror diameter; the value of D is used for the definition of h_o since it is very nearly equals the pupil height and represents a limit in any case.

At intermediate points at the entrance slit of h/h_o (note, $0 < h/h_o < 1.0$) the etendue will be determined by the overlap of the source exit pupil and the projected receiver entrance pupil. Figures 3.3.2.3, 3.3.2.4 and 3.3.2.5 show the overlap or net transmitting area as a cross-hatched region for grating angles of 20, 30 and 40 degrees respectively for various values of h/h_o. The areas shown (reduced by an allowance for a 2 mm wide support strut on the mask) were measured by means of a planimeter and normalized by the net unobscured area of the telescope primary mirror. The vignetting factor, V, is defined

$$V = \frac{A_2(h/h_o, \theta)}{A_o}$$

where $A_2(h/h_o, \theta)$ = net transmitting area of pupils

A_o = net unobscured primary mirror area

$= (\pi/4)(24^2 - 10^2) = 373.8 \text{ in}^2 = 2412 \text{ cm}^2.$

The values for V are as shown on Figure 3.3.2.6. Here the primary mirror outside diameter is 24.0 inches (60.96 cm) and the central obscuration diameter is 10.0 inches (25.4 cm).

Strictly speaking the values of V obtained above are for points along the length of the entrance slit. Slightly different values would be obtained for points along the width of the slit.

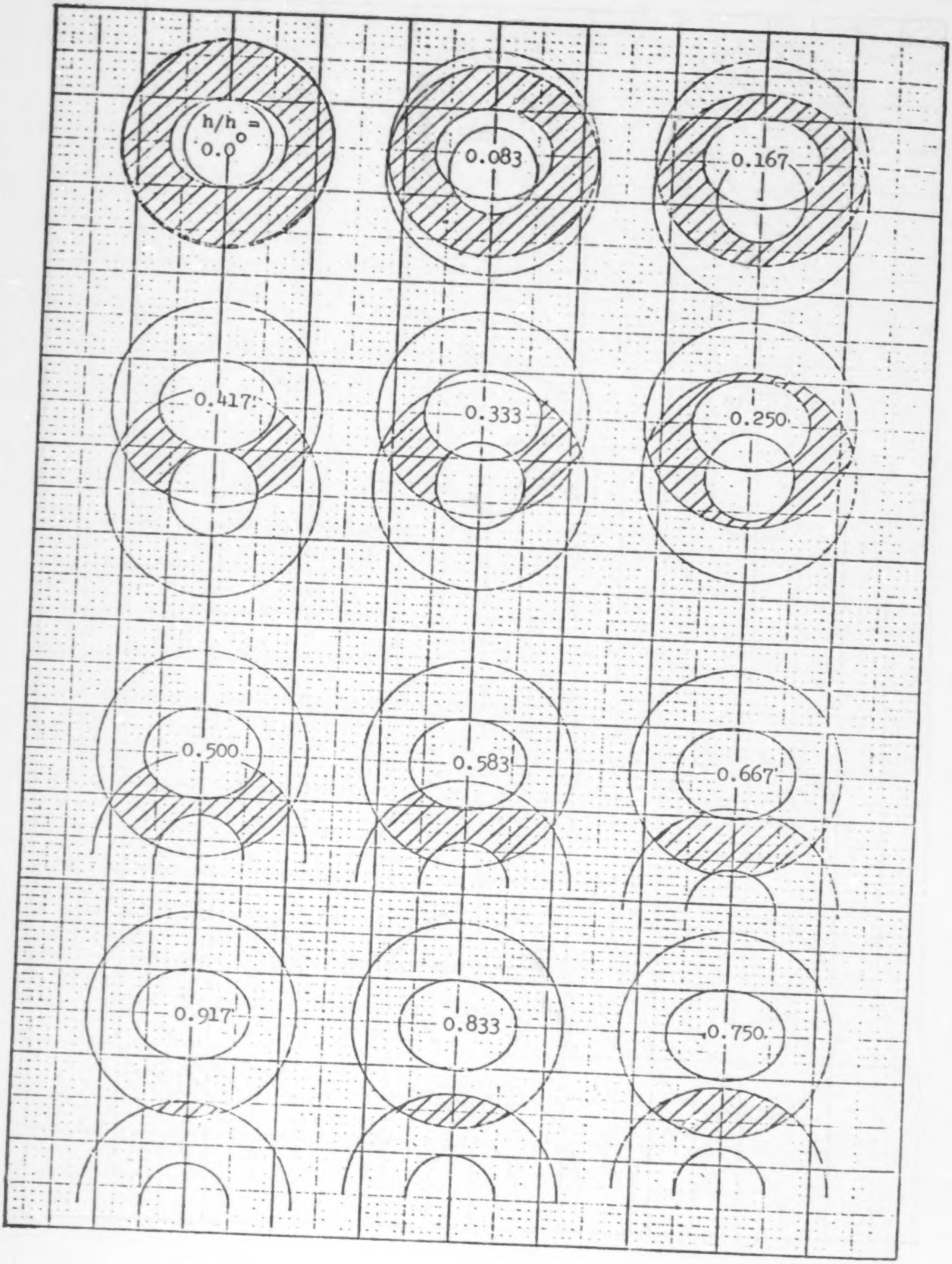


Figure 3.3.2.3 Net Transmitting Area - $\theta = 20^\circ$

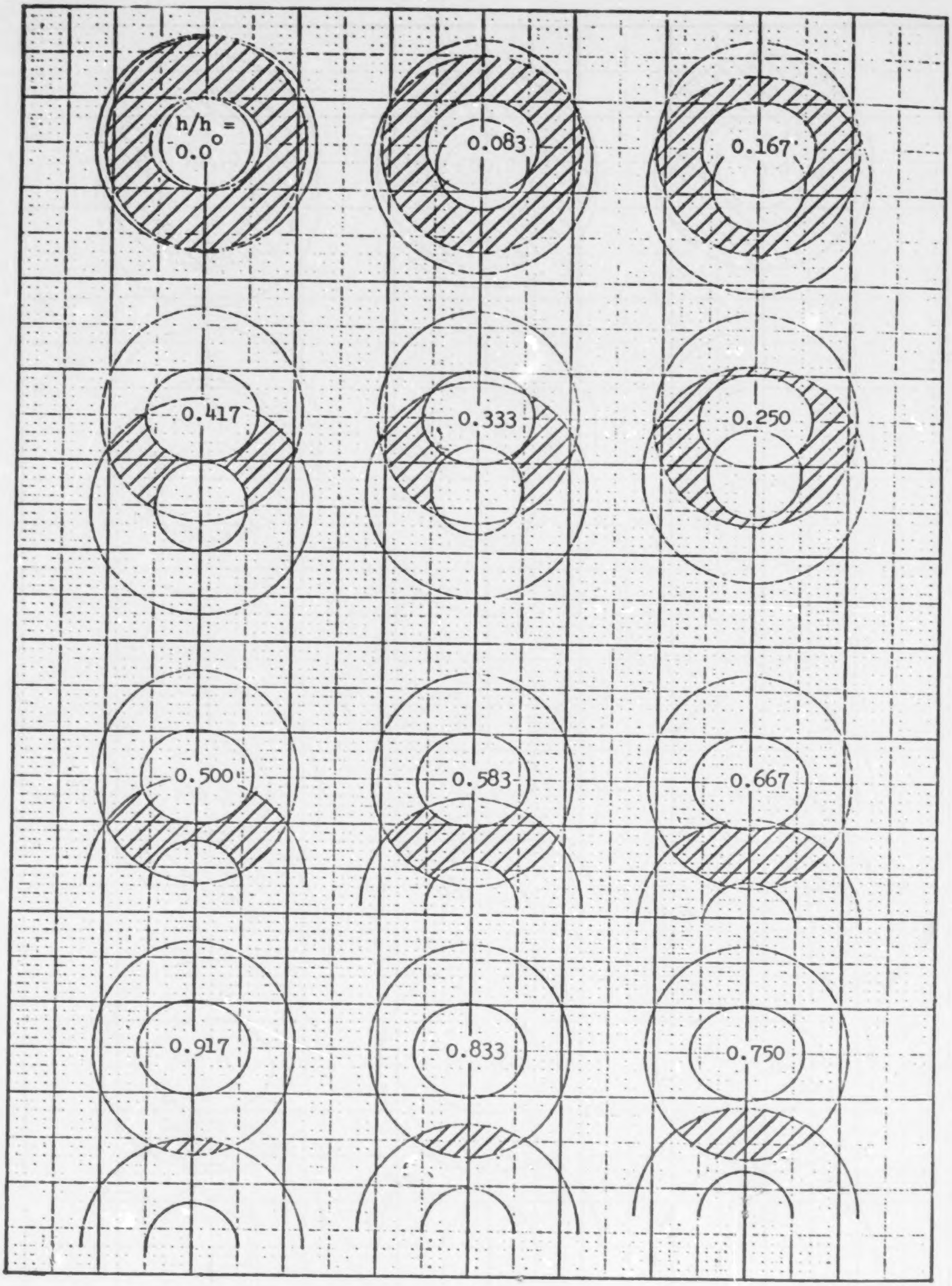


Figure 3.3.2.4 Net Transmitting Area - θ = 30°

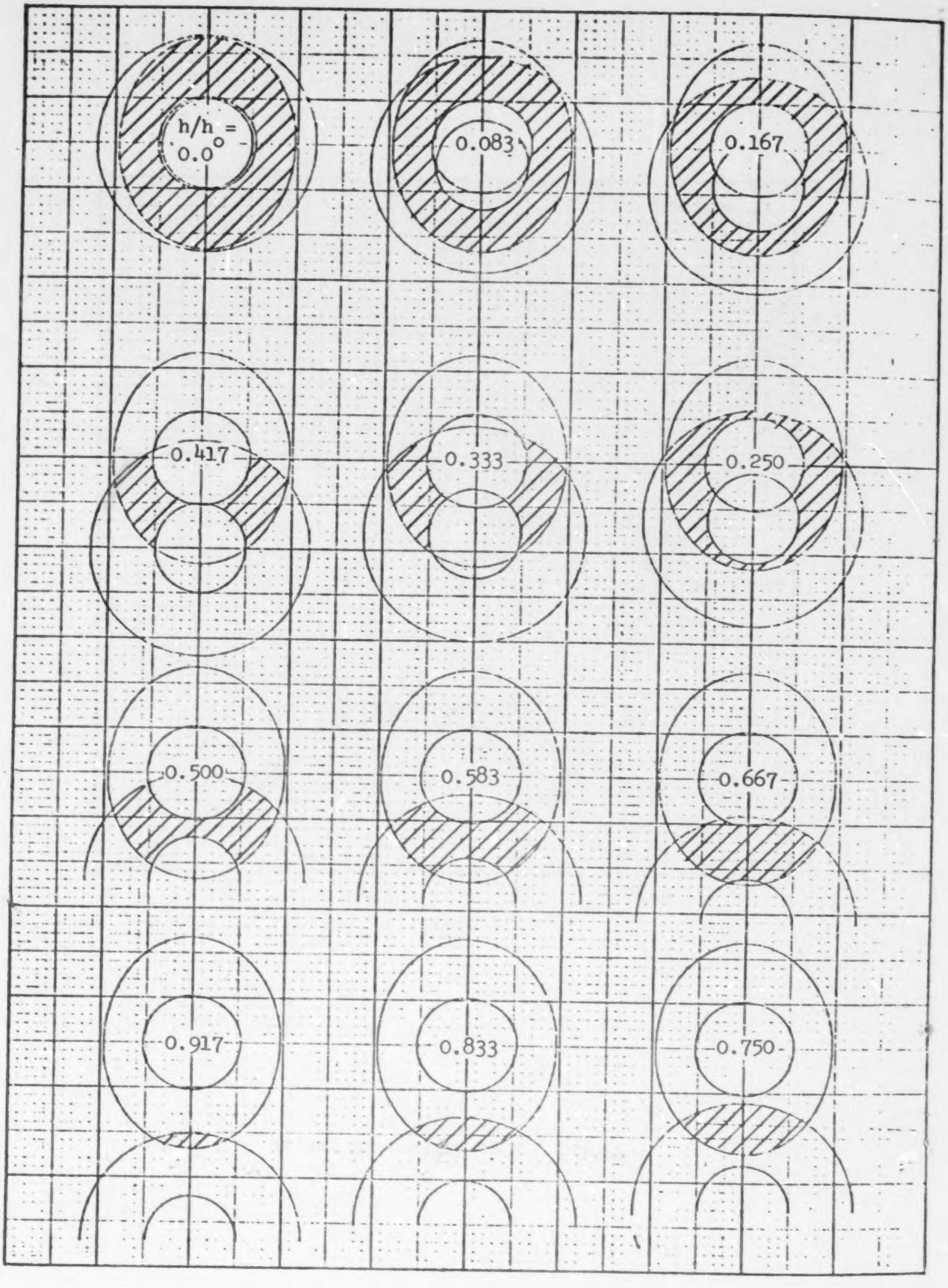


Figure 3.3.2.5 Net Transmitting Area - θ = 40°

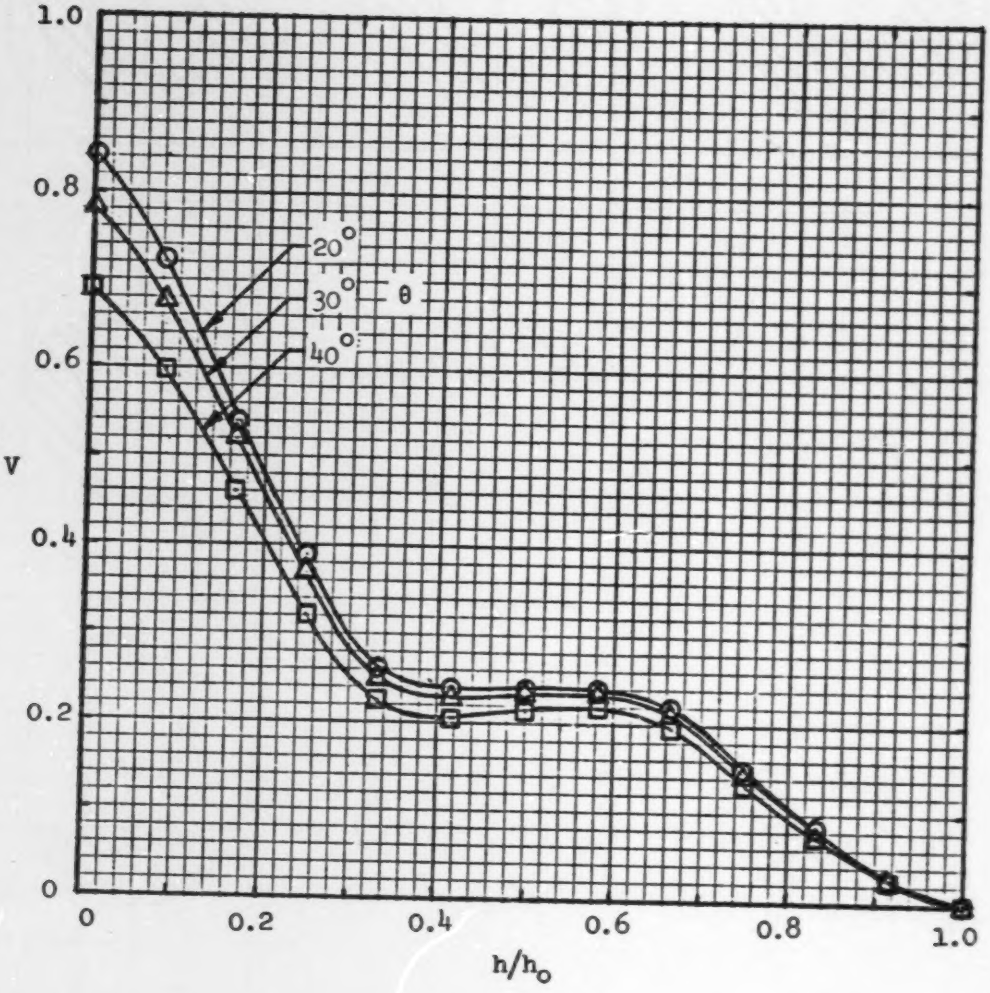


Figure 3.3.2.6 Vignetting Factor

Because of time limitations and the fact that the vignetting factors in the two directions are similar, the values along the slit were assumed to be independent of azimuth (about the optical axis).

$A_2(r/h_o, \theta)$

with $r^2 = s^2 + h^2$

The etendue for the transmission mode of operation source beam is the integral within the boundaries of the slit width and height.

$$dA\Omega_t = A_2(r/h_o,\theta)\ ds\ dh/F^2$$

$$= \frac{h_o^2}{F^2} A_2(r/h_o, \theta)\ d(s/h_o)\ d(h/h_o)$$

$$= \frac{A_o h_o^2}{F^2} V(r/h_o, \theta)\ d(s/h_o)\ d(h/h_o)$$

$$A\Omega_t = \frac{A_o h_o^2}{F^2} \int_o^{h/h_o} \int_o^{s/h_o} V(r/h_o, \theta)\ d(s/h_o)\ d(h/h_o)$$

$$= \frac{A_o h_o^2}{F^2} (s/h_o)\ (h/h_o)\ \overline{V}$$

$$\text{where } \overline{V}\ (s/h_o)(h/h_o) = \int_o^{h/h_o} \int_o^{s/h_o} V(r/h_o, \theta)\ d(s/h_o)\ d\ (h/h_o)$$

The integration was carried out numerically using a digital computer. On the basis of test cases the truncation error is believed to be less than 7% (in most cases considerably less). Values of $\overline{V}/\cos\theta$ were compared for various values of s/h_o and h/h_o and found to be equal within about 5% average.

It is convenient, therefore, to express AΩ as follows for the transmission mode of operation source beam:

$$A\Omega_t = \frac{A_o h_o^2 \cos\theta}{F^2} \left[\frac{\bar{V}\,(s/h_o)(h/h_o)}{\cos\theta}\right]_{avg}$$

where A_o = net unobscured primary mirror area

h_o = image height = 2FD/R (see Figure 3.3.2.7)

θ = grating angle (see Figure 3.3.2.8)

F = telescope focal length

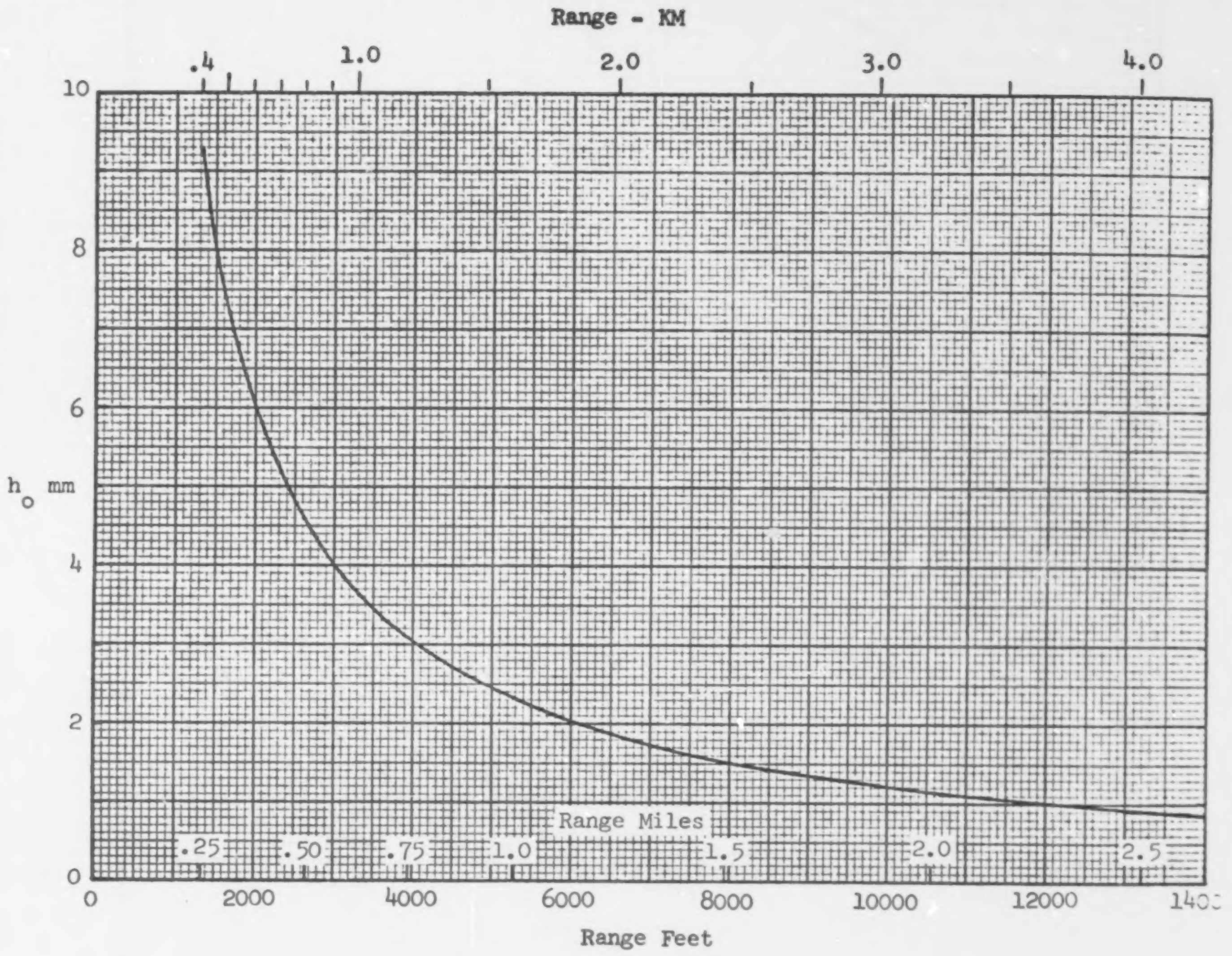
and the bracketed term is the average integrated vignetting factor, see Figure 3.3.2.9.

In the transmission mode of operation the ratio $(A\Omega_t/A\Omega_c)$ is of interest. This ratio may be written,

$$\frac{A\Omega_t}{A\Omega_c} = \frac{A_o h_o^2 \cos\theta \left[\bar{V}\,(s/h_o)(h/h_o)/\cos\theta\right]_{avg}}{(s)(h)(A_2\cos\theta}$$

$$= \frac{A_o}{A_2}\left[\bar{V}/\cos\theta\right]_{avg}$$

This ratio is shown on Figure 3.3.2.10 as a function of (s/h_o) and h/h_o.



$$h_o = \frac{2DF}{R}$$

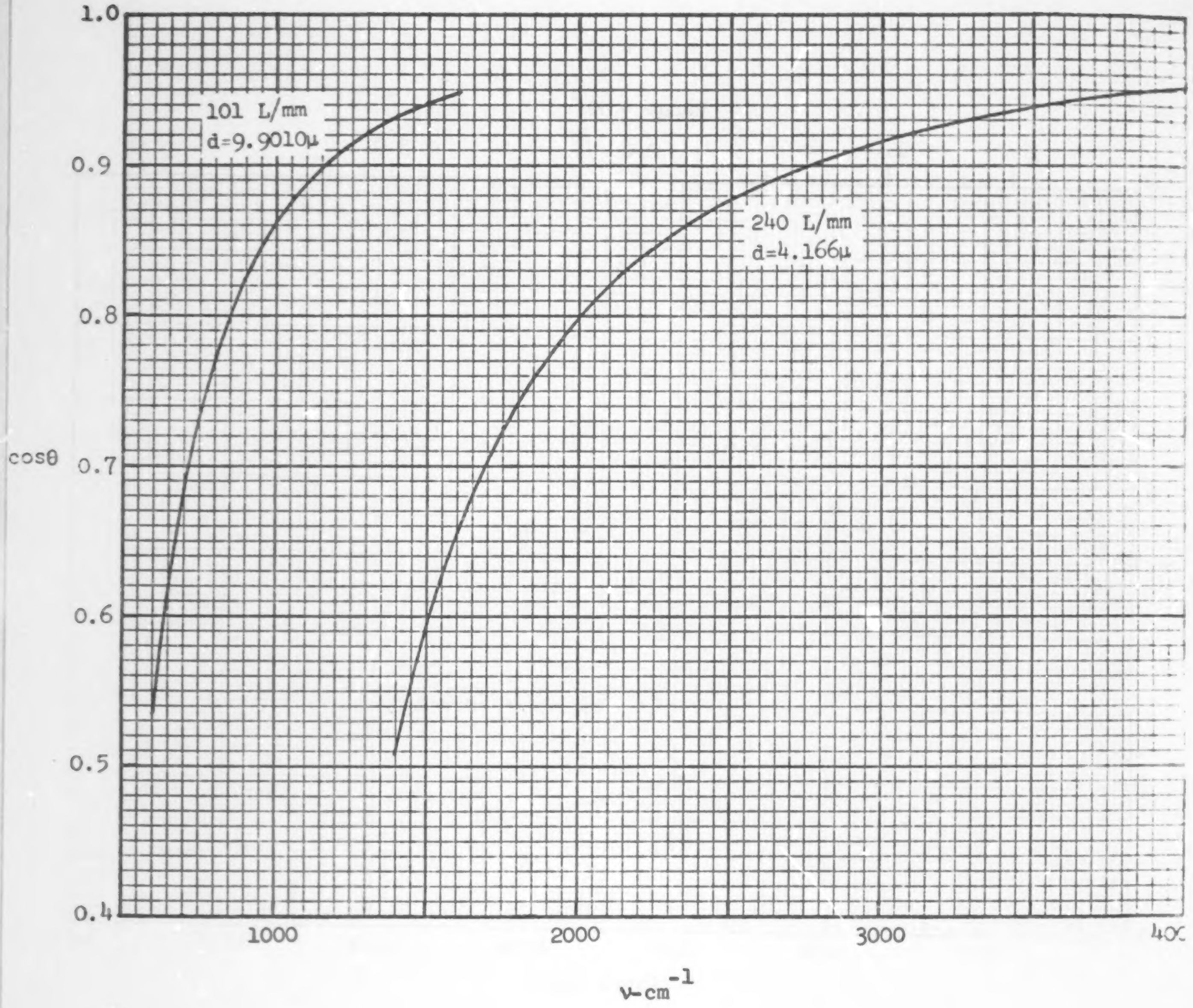
D = Telescope Dia = 2 Ft.

R = Range -Ft

F = Telescope F.L. = 3049 mm

h_o = Total Image Ht -mm

Figure 3.3.2.7 Total Image Height Vs. Range



$$\sin\theta = \frac{10^4}{2\nu d\cos\phi}$$

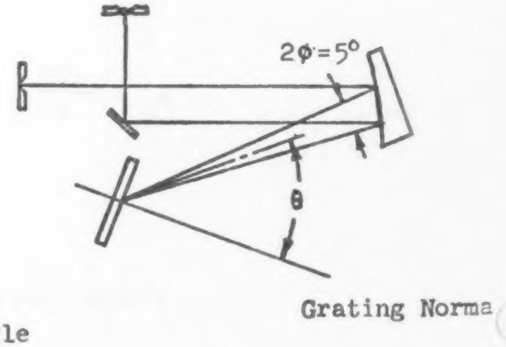


Figure 3.3.2.8 Grating Angle

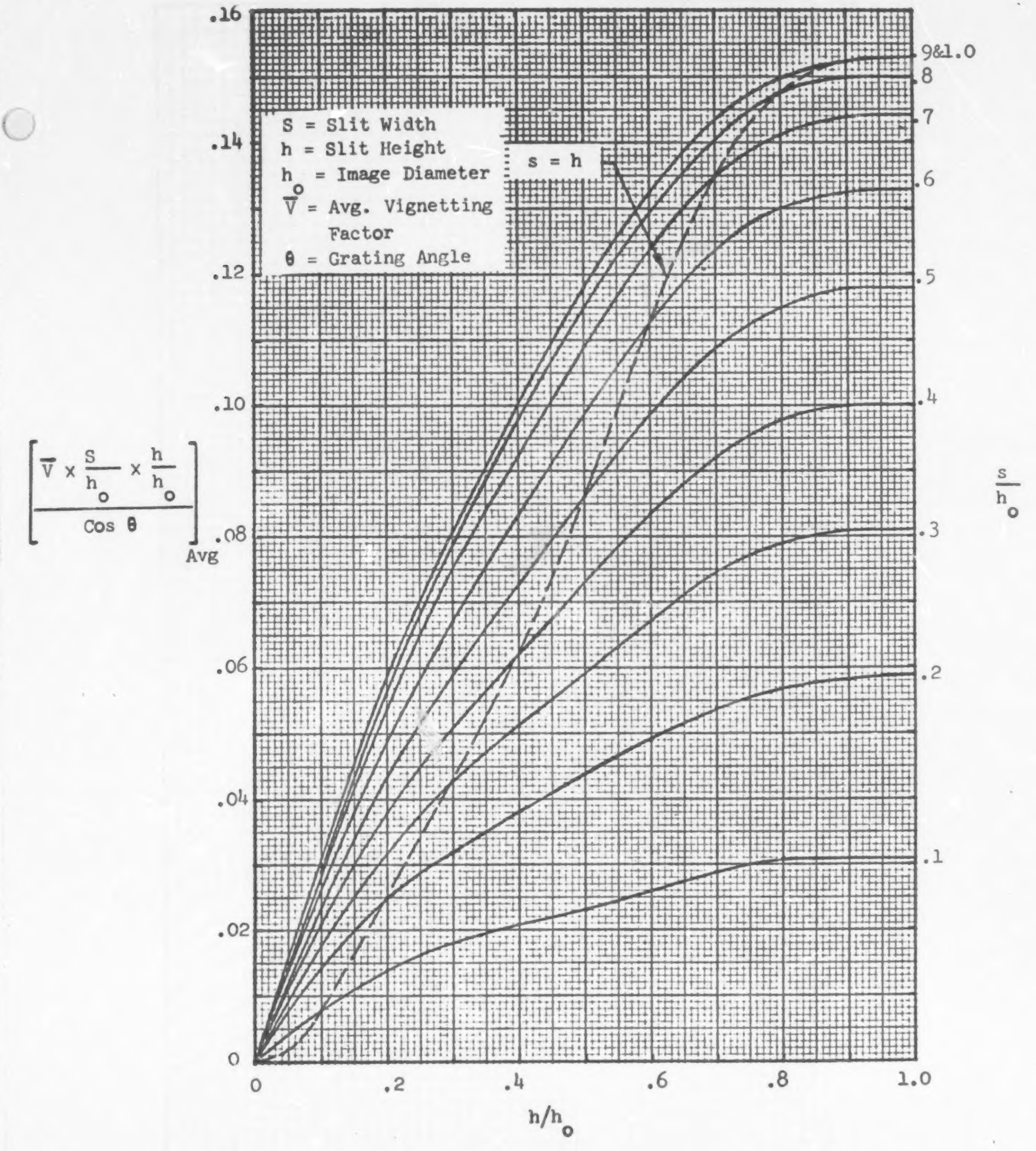


Figure 3.3.2.9 Average Integrated Vignetting Factor

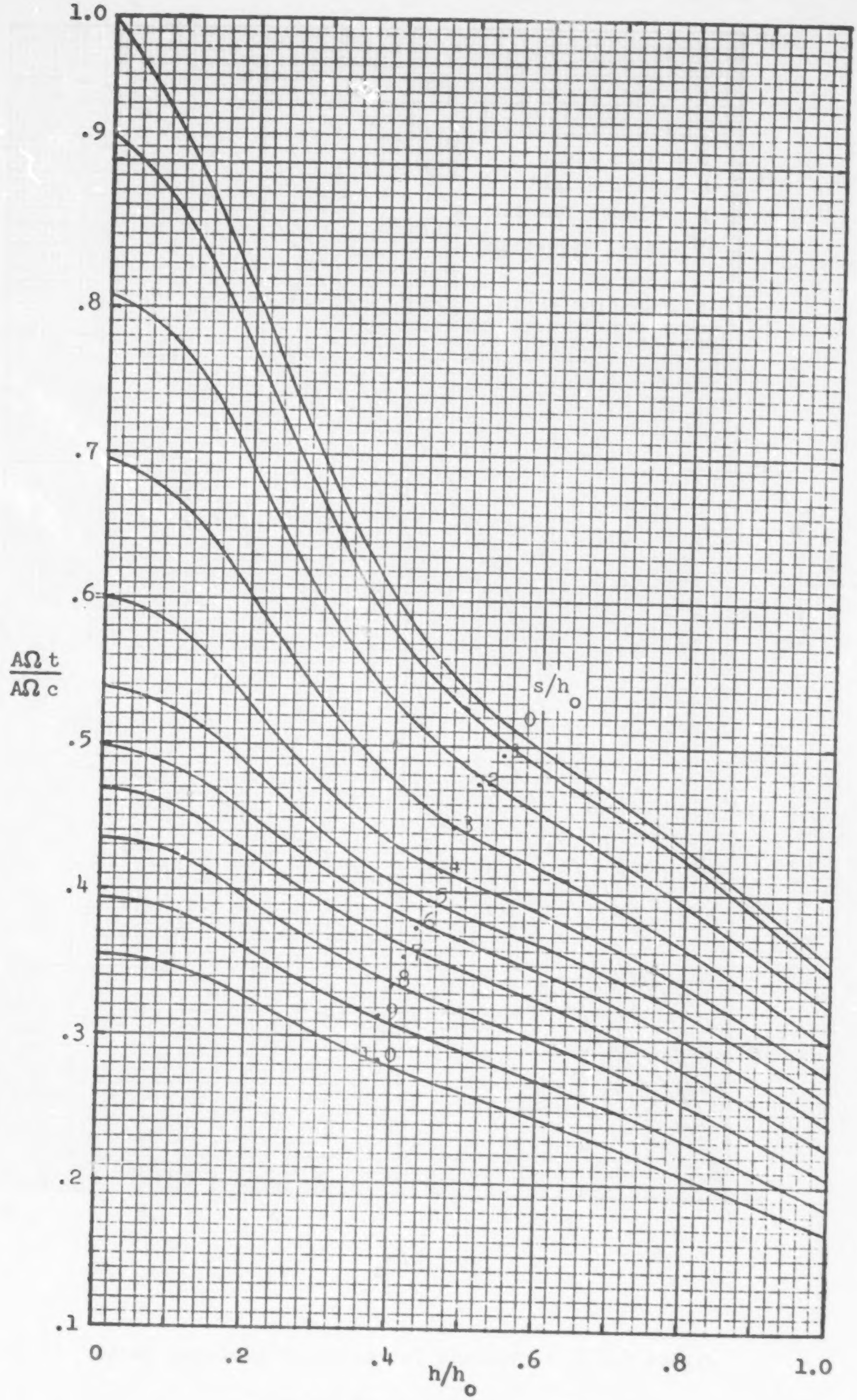


Figure 3.3.2.10 Etendue Ratio

3.3.3 Transmission

There are several transmitting factors which control the flux:

1. Transmission of Irtran 2 field lenses and window
2. Reflectivity of aluminum surfaces
3. Transmission of grating
4. Transmission of atmosphere

Irtran 2

There are two Irtran 2 field lenses one just ahead of the monochromator entrance slit and the other in the detector optical system. There is one Irtran 2 window mounted on the dewar which contains the detector. Each is about 2 mm thick at the center and since the lenses are weak the thickness variation is small. Figure 3.3.3.1 shows the typical spectral transmittance of a 2 mm thick Irtran 2 element taken from a recent Kodak publication. Also shown is the measured transmission of the field lens (used at the monochromator entrance slit) at 0.63 microns. The lower curve for three elements in series was obtained by raising the transmittance values for one element to the third power. The large variation from sample to sample of transmittance in the visible region of the spectrum is common among Irtran elements; in the infrared region Kodak quotes variations of about 2% may be expected.

Aluminum Reflectivity

All of the mirrors in the system are coated with aluminum protected by approximately a quarter wave (visible) of silicon monoxide. The grating is aluminized but is not known if a protective coating is applied or not.

Results of reflectance measurements on samples provided by Perkin Elmer for each telescope are shown on Figure 3.3.3.2.

The reflectance of aluminum protected by a quarter wave ($\sim$ 1200-1500μ) of silicon monoxide has been reported by G. Hass and N.W. Scott (JOSA 39 179 (1949) and are also shown on Figure 3.3.3.2 as circles.

There are 12 mirror reflecting surfaces in the transmission mode of operation and 10 surfaces in the emission mode of operation. Both include the grating as a reflecting surface. Taking the telescope reflectance values as typical the reflectance values for the system may be obtained by raising the reflectance value for one surface to the 10th and 12th power. These values are also shown on Figure 3.3.3.2.

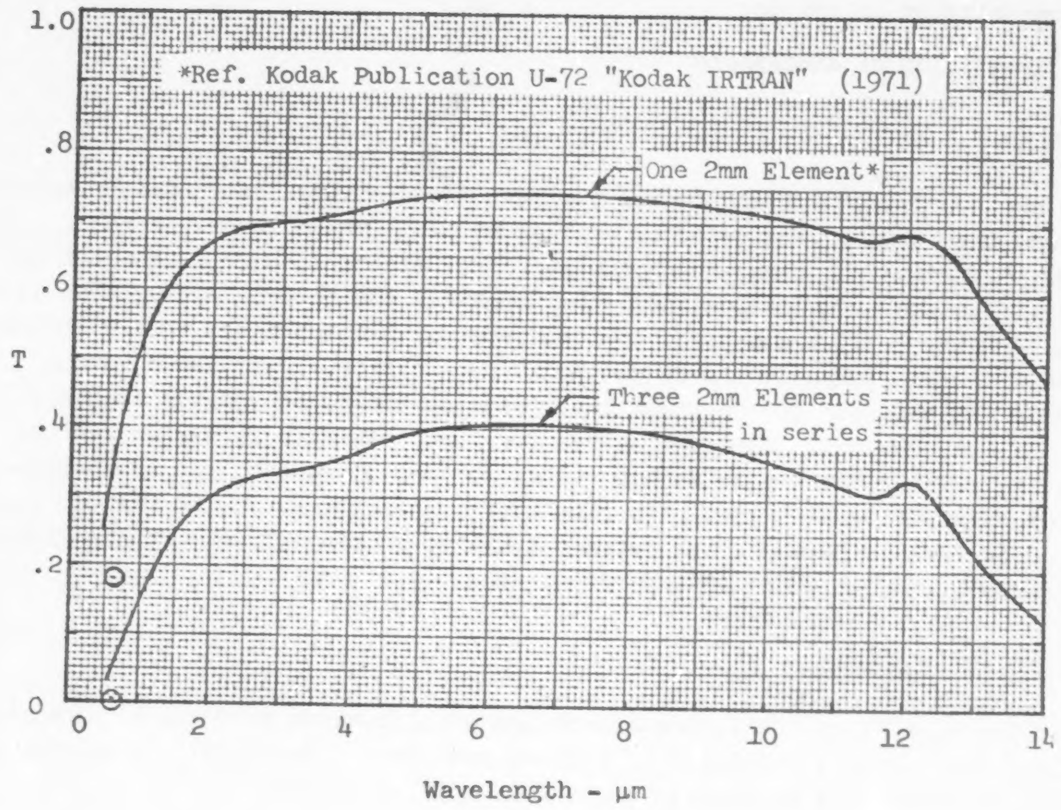


Figure 3.3.3.1 External Specular Transmittance - IRTRAN 2 (Uncoated)

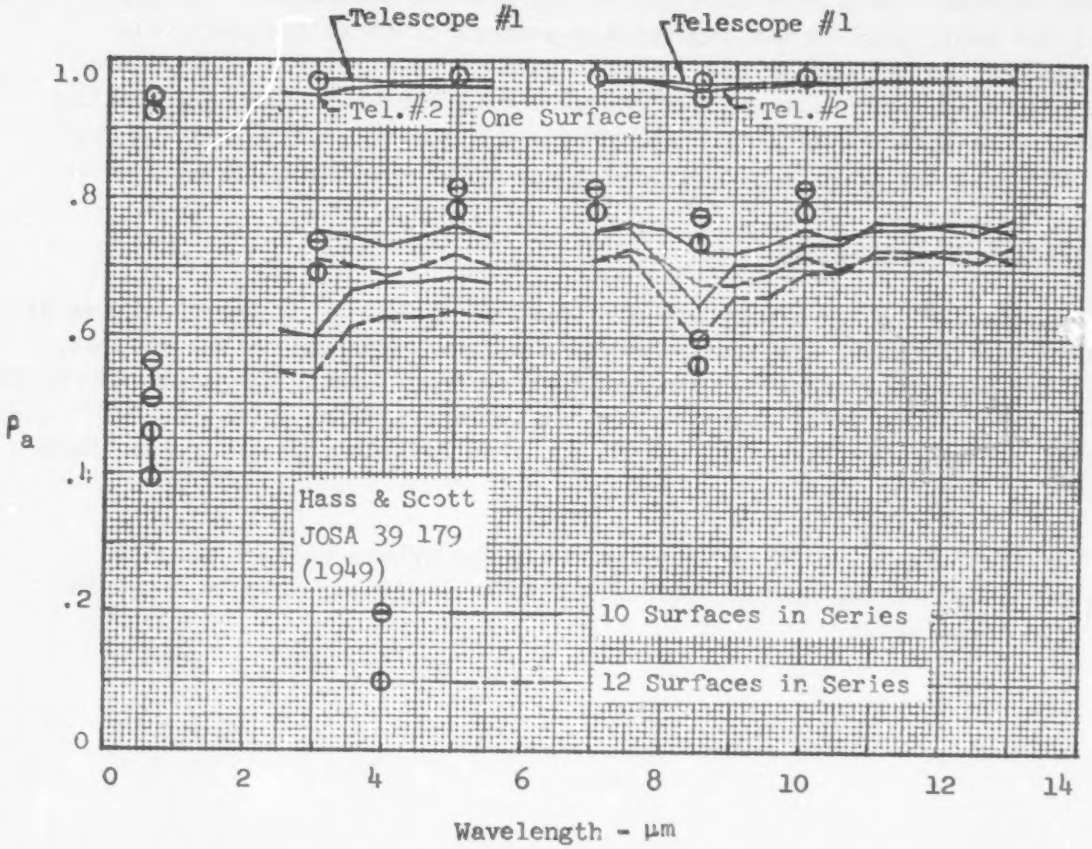


Figure 3.3.3.2 Aluminum Reflectance

Grating Efficiency

The efficiency of a grating is defined as the monochromatic flux relative to that for a good aluminized flat mirror used in place of the grating. Therefore, the efficiency does not include the reflectance of the aluminized grating surface. Data were provided by the grating manufacturer (Perkin Elmer) for tools used in the replication process close to the particular gratings used in this instrument. These data shown on Figure 3.3.3.3 are for unpolarized input (i.e., polarized at 45° to the azimuth of the grating grooves). Data for polarizations of 0° and 90° for the master grating from which the gratings used in the present instruments were made are also shown.

Transmission of Atmosphere

The transmission of the atmosphere will include that from normal constituents as well as pollutants. Molecular absorption from water and carbon dioxide, as well as absorption from aerosols will be of importance. The exact absorption for any given setup will depend on the particular existing conditions of humidity, temperature, aerosol content and size distribution and range (path length).

For the purposes of this report a clean atmosphere will be assumed; examples of actual absorption under field test conditions will be shown in the field test report.

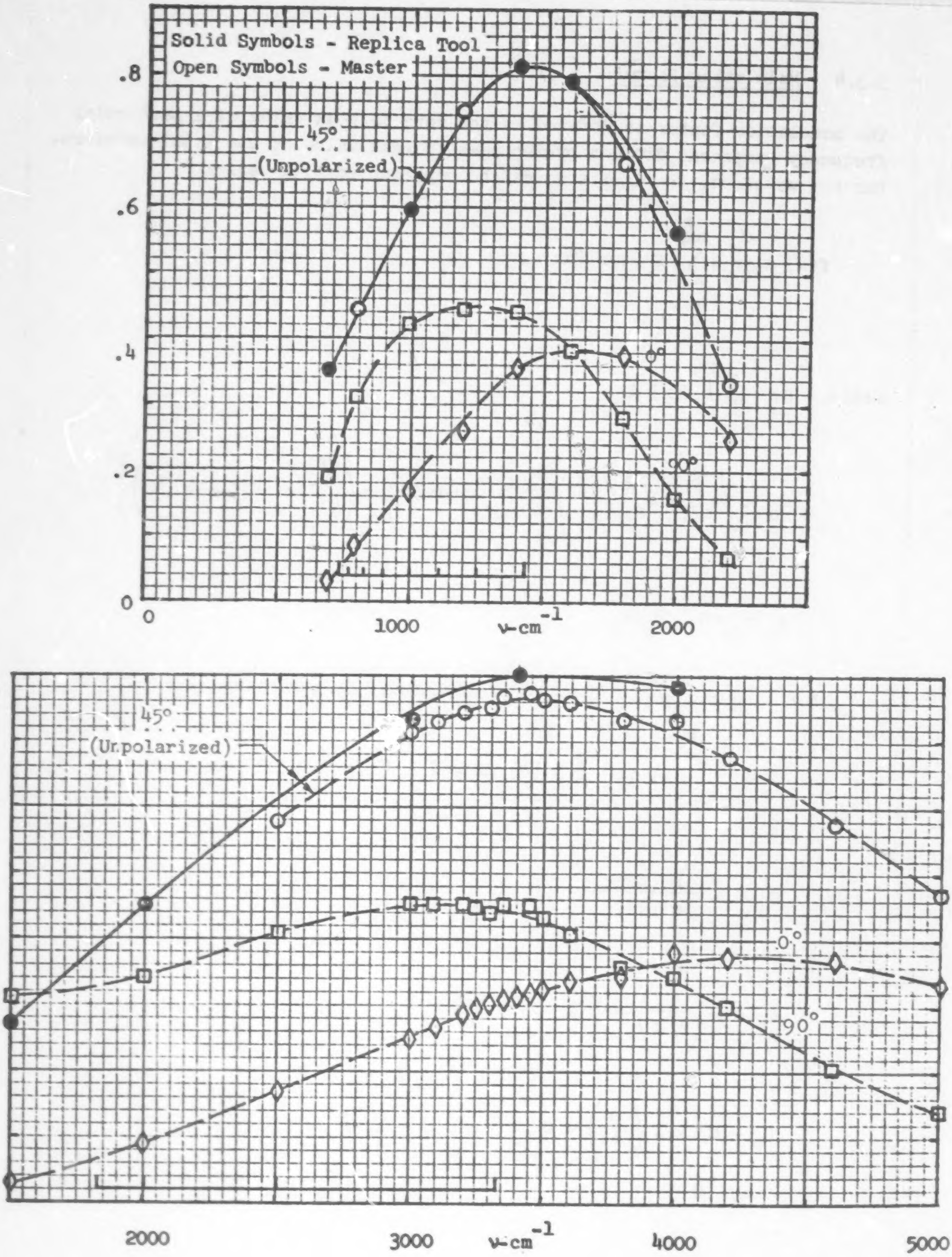


Figure 3.3.3.3 Grating Efficiency Ref. Perkin Elmer

3.3.4 Modulation Factor

The modulation factor is defined as the zero to peak value of a particular frequency component divided by the peak to peak value of the total waveform. For any waveform, the amplitude can be represented by a series.

$$f(x) = \frac{C_o}{2} + \sum_{n=1}^{n=\infty} C_n \cos(nx + \phi_n)$$

where $C_o = \frac{1}{\pi}\int_0^{2\pi} f(x)\,dx$

$$C_n = \sqrt{A_n^2 + B_n^2} = \left[\left(\int_0^{2\pi} f(x)\cos(nx)dx\right)^2 + \left(\int_0^{2\pi} f(x)\sin(nx)\,dx\right)^2\right]^{\frac{1}{2}}$$

$$\phi_n = \tan^{-1} B_n/A_n$$

For a square wave t/T = 0.5 of amplitude, N, for example,

$$C_o = \frac{1}{\pi}\int_0^{n} (N)\,dx + \frac{1}{\pi}\int_n^{2n} (0)\,dx = N$$

$$C_n = N\,\frac{\sin(n\pi/2)}{(n\pi/2)}$$

$$C_1 = N\left(\frac{1}{\pi/2}\right) = \frac{2}{\pi}N$$

$$C_2 = C_4 = N\left(\frac{0}{\pi}\right) = 0$$

$$C_3 = N\left(\frac{-1}{3\pi/2}\right) = \frac{-2}{3\pi} N$$

$$C_5 = N\left(\frac{1}{5\pi/2}\right) = \frac{2}{5\pi} N$$

and $\phi_n = 0$

Thus for the square wave.

$$\frac{f(x)}{N} = \frac{1}{2} + \frac{2}{\pi} \cos x - \frac{2}{3\pi} \cos 3x + \frac{2}{5\pi} \cos 5x \ldots$$

The peak to peak value of each frequency component is just twice the value of the above coefficients and the rms value of each frequency component is $(1/\sqrt{2})$ times the value of the above coefficients. For the case of a square wave, then:

n	C_n/N = Mod. Factor
1	$(2/\pi) = 0.63662$
2	0
3	$2/3\pi = 0.21221$
4	0
5	$2/5n = 0.12732$

By way of illustration the following description is given of the radiance variation (neglecting reflection and other losses for now to simplify the description). Square wave chopping is assumed to make clear the numerical coefficients.

Consider the case at short range in which the reference chopper is not running (open). As shown at the top of Figure 3.3.4.1 the total wave form radiance varies between the hot blackbody source radiance, N^{o} (λ, T_s), and the room temperature (assumed black) chopper wheel radiance, $N_W^{os}(\lambda, T_W)$.

Let $\Delta N = N_s^{o}(\lambda, T_s) - N_W^{o}(\lambda, T_W)$.

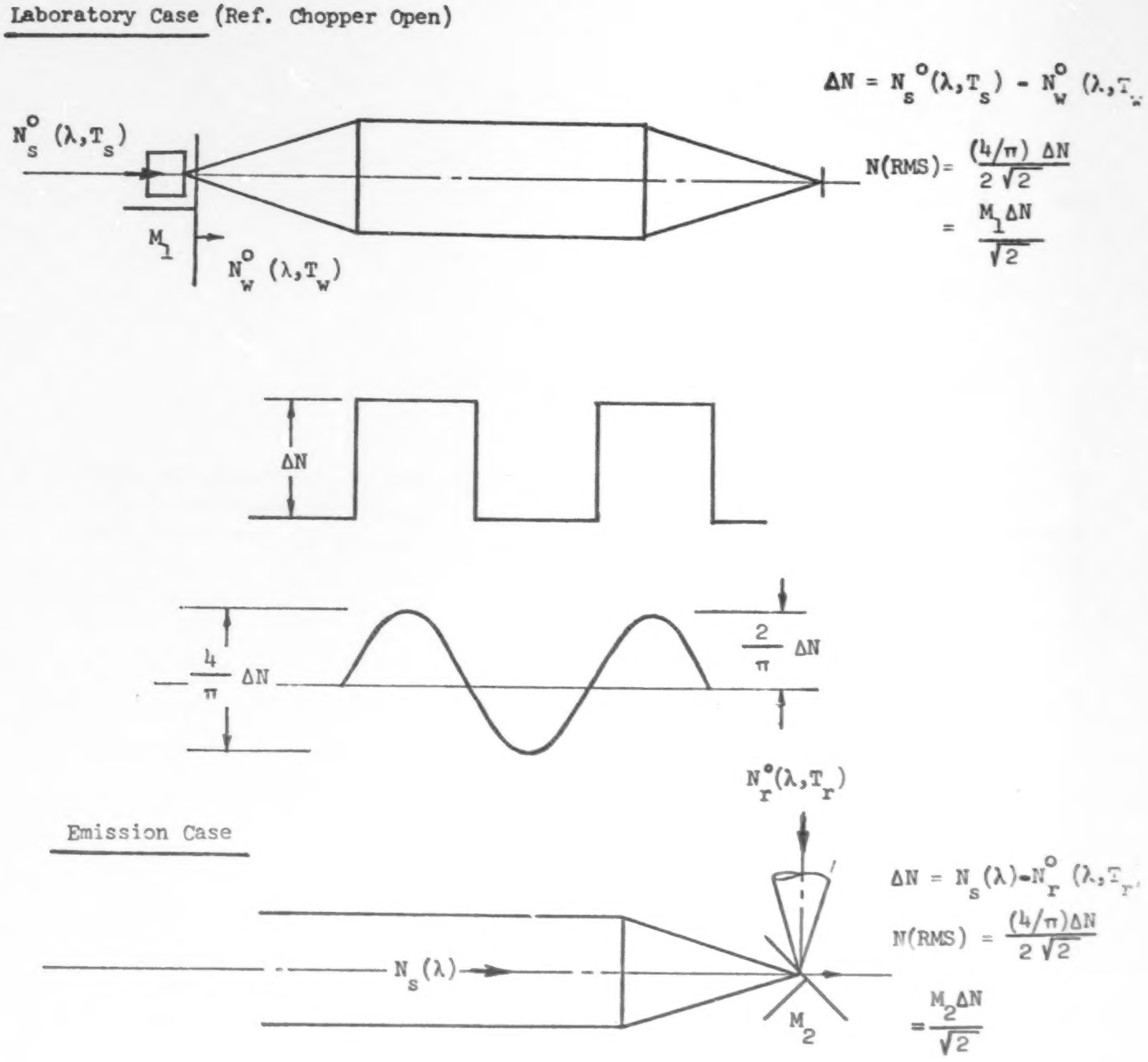

Laboratory Case (Ref. Chopper Open)
$\Delta N = N_s^o(\lambda,T_s) - N_w^o(\lambda,T$
$N_s^o(\lambda,T_s)$
$N(RMS) = \frac{(4/\pi)\,\Delta N}{2\sqrt{2}}$
$= \frac{M_1 \Delta N}{\sqrt{2}}$
M_1
$N_w^o(\lambda,T_w)$
ΔN
$\frac{4}{\pi}\,\Delta N$
$\frac{2}{\pi}\,\Delta N$
$N_r^o(\lambda,T_r)$
Emission Case
$\Delta N = N_s(\lambda) - N_r^o(\lambda,T_r$
$N(RMS) = \frac{(4/\pi)\Delta N}{2\sqrt{2}}$
$= \frac{M_2 \Delta N}{\sqrt{2}}$
$N_s(\lambda)$
M_2

Figure 3.3.4.1 Single Chopper Modulation

The first Fourier coefficient (for the fundamental frequency) equals $(2/\pi)$ so that the peak to peak variation of the fundamental radiance is $(4/\pi)\Delta N$. The RMS value of the fundamental radiance variation $(4/\pi)\ (\Delta N)/2\sqrt{2} = (2/\pi)\ (\Delta N)/\sqrt{2} = M_1 \Delta N/\sqrt{2}$. The selective amplifier selectively passes the fundamental frequency and is calibrated in terms of the RMS value of the fundamental frequency.

Next consider the emission case in which only the reference chopper is being used. The total wave form radiance varies between the assumed warm emission source radiance, $Ns\ (\lambda)$, and the room temperature reference blackbody radiance, $N_r^o\ (\lambda,\ T_r)$. In this case M_2 replaces M_1,

$$\Delta N = N_s(\lambda) - N_r^o(\lambda, T_r)$$

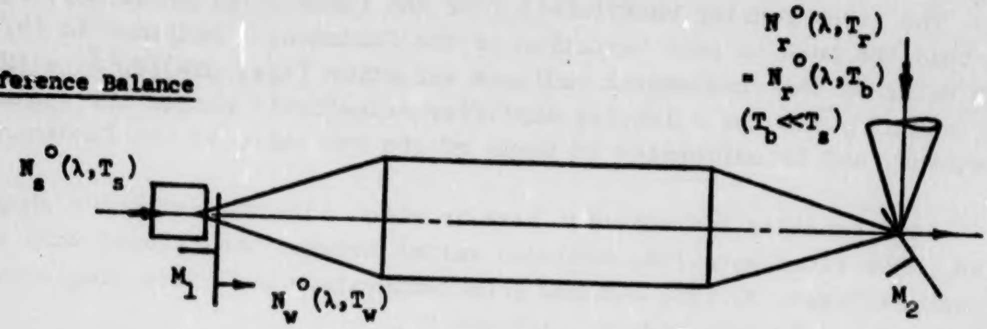
and the same numerical factor of $\sqrt{2}$ as that for the laboratory case appears in the denominator. This factor also appears, of course, in the emission mode of operation equations for the detector voltage, S_d (RMS), and the lock-in amplifier output, S_{xr}.

For the transmission mode of operation dual choppers are used. In this description only the most important radiance terms are used for clarity. Figure 3.3.4.2 shows the relations for the preliminary reference balance and for the operating condition for the transmission mode.

The value of $\bar{N}$ for the ω_2 reference balance is a complicated combination of low temperature radiance whose total effects are cancelled out in the balance procedure. Note that for the reference balance the ΔN's for both ω_1 and ω_2 contain $(A\Omega_t/A\Omega_c)$ and $(1-\alpha)$; therefore the balance is independent of vignetting or absorption. The factor of 1/2 in the reference balance equations for ΔN represents the fact that the source beam is chopped by both choppers. Although this factor appears to be arbitrary here, no such arbitrary factors were put in the full analysis given previously; this factor developed from the equations themselves.

For operation in the transmission mode, $T_r = T_s$ and again the 1/2 factor appears in the source radiance (but not the reference radiance) for the reason given above. Note also that the factors $(A\Omega_t/A\Omega_c)$ and $(1-\alpha)$ now appear only in the source radiance. The factor $(1-\alpha)$ contains the desired transmission information. The factor $(A\Omega_t/A\Omega_c)$ is a consequence of vignetting which is important for long path lengths but negligible for short paths (such as those in the laboratory). The τ_{sig} control is used to make $(1-\alpha)$ direct reading and, because of the $(A\Omega_t/A\Omega_c)$ factor, must have an extra range of adjustment.

Reference Balance


$N_r^{\circ}(\lambda,T_r)$
$= N_r^{\circ}(\lambda,T_b)$
$(T_b \ll T_s)$
$N_s^{\circ}(\lambda,T_s)$
M_1
$N_w^{\circ}(\lambda,T_w)$
M_2

AT ω_1 (Source Freq.):

$$\Delta N = \left[N_s^{\circ}(\lambda,T_s) - N_w^{\circ}(\lambda,T_w)\right](A\Omega_t/A\Omega_c)(1-\alpha)$$

$$N(RMS) = ((4/\pi)\Delta N/2/2)\ (\tfrac{1}{2})$$

$$= (2/\pi)\Delta N/2/2$$

$$= M_1\Delta N/2/2$$

AT ω_2 (Ref. Freq.):

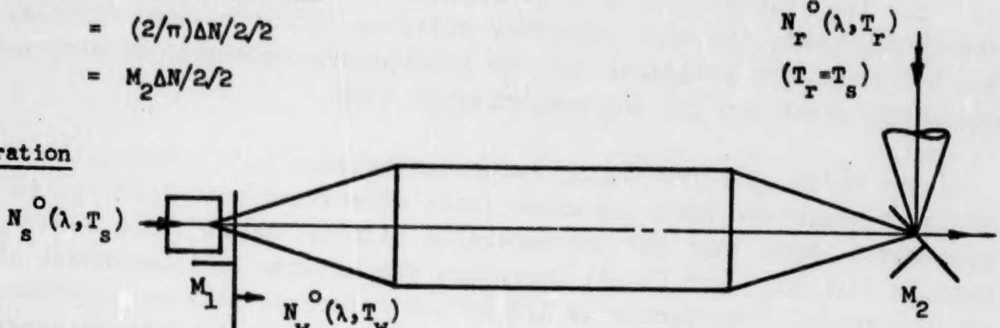
$$\Delta N = \left[N_s^{\circ}(\lambda,T_s) - \bar{N}\right]\ (A\Omega_t/A\Omega_c)(1-\alpha)$$

$$N(RMS) = ((4/\pi)\Delta N/2/2(\tfrac{1}{2})$$

$$= (2/\pi)\Delta N/2/2$$

$$= M_2\Delta N/2/2$$

Operation


$N_r^{\circ}(\lambda,T_r)$
$(T_r = T_s)$
$N_s^{\circ}(\lambda,T_s)$
M_1
$N_w^{\circ}(\lambda,T_w)$
M_2

AT ω_1 (Source Freq.):

$$\Delta N = \left[N_s^{\circ}(\lambda,T_s) - N(\lambda,T_w)\right]\ (A\Omega_t/A\Omega_c)(1-\alpha)$$

$$N = (RMS) = ((4/\pi)\Delta N/2/2)(\tfrac{1}{2})$$

$$= (2/\pi)\Delta N/2/2$$

$$= M_1\Delta N/2/2$$

AT ω_2 (Ref. Freq.):

$$\Delta N = \left[N_r^{\circ}(\lambda,T_r) - N_r^{\circ}(\lambda,T_b)\right]$$

$$N(RMS) = ((4/\pi)\Delta N/2/2$$

$$= (2/\pi)\Delta N//2$$

$$= M_2\Delta N//2$$

Figure 3.3.4.2 Dual Chopper Modulation

The modulation factors of the source chopper, M_1, and the reference chopper, M_2, are evaluated by means of Figure 3.3.4.3. On this figure are shown the values of the ratio of the RMS value of the fundamental component to the peak to peak value of the total signal for both a circular aperture and a rectangular aperture modulated linearly by alternating open and opaque bands of equal width. Data for the circular case were obtained from Santa Barbara Research Center. Values for the rectangular case were obtained from the Fourier coefficients given in "Reference Data for Radio Engineers" ITT Corporation (1949) for trapezoidal waveforms.

For the reference chopper the beam width the chopper is about 19mm and the centerline blade width is about 34.4 mm giving $D/W \sim 0.55$ and $M_2 \sim 0.58$ (using the circular aperture curve).

For the source chopper the beam width is from 0 to 2mm depending on slit width. The centerline blade width is about 8.3mm giving $(D/W)_{max} \sim 0.24$ and $M_1 \sim 0.64$ to 0.62 using the rectangular aperture curve. An average value of $M_1 = 0.63$ may be assumed.

$$\text{Modulation Factor} = \frac{\text{0 to Peak Fundamental}}{\text{Peak to Peak Total Wave}}$$

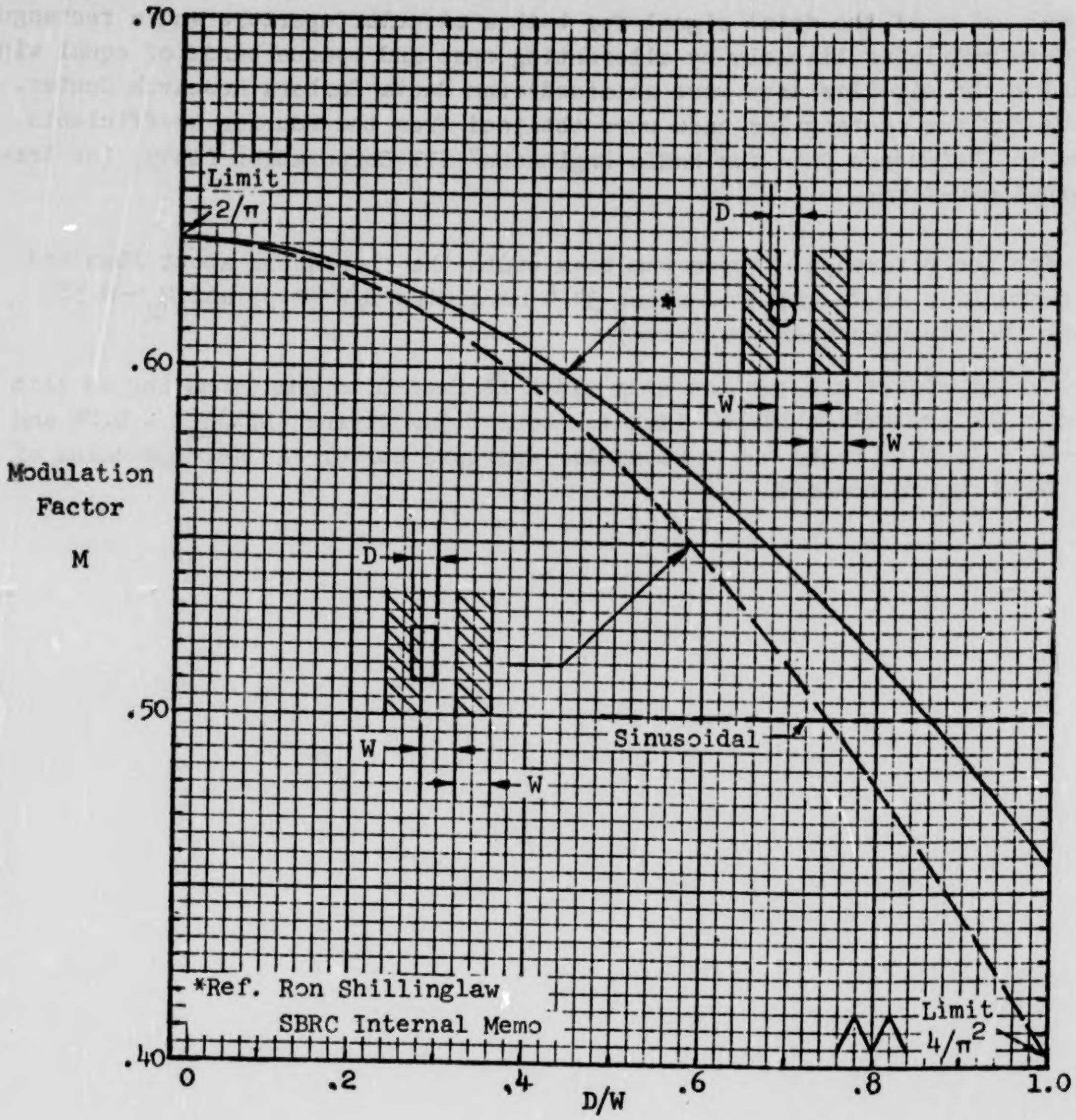


Figure 3.3.4.3 Modulation Factor

3.3.5 Spectral Slit Width

For a uniform non-coherent entrance slit irradiance the intensity distribution in the image at the exit slit may be expressed by an equation derived by van Cittert* which expresses the image intensity as a function of the image coordinate x (in the dispersion direction) and the slit width, S. Both x and S are normalized by the diffraction halfwidth, a, which is the distance between the image center and the first minimum of the diffraction pattern for S = 0.

$$J = \frac{1}{\pi}\left\{ \mathrm{Si}\left[2\pi\left(\frac{S}{2a} - \frac{x}{a}\right)\right] + \mathrm{Si}\left[2\pi\left(\frac{S}{2a} + \frac{x}{a}\right)\right] - \frac{\sin^{2}\pi\left(\frac{S}{2a} - \frac{x}{a}\right)}{\pi\left(\frac{S}{2a} - \frac{x}{a}\right)} - \frac{\sin^{2}\pi\left(\frac{S}{2a} + \frac{x}{a}\right)}{\pi\left(\frac{S}{2a} + \frac{x}{a}\right)} \right\} \qquad (1)$$

where $\mathrm{Si}(\alpha) = \int_{0}^{\alpha} \frac{\sin \alpha}{\alpha}\, d\alpha$

s = slit width (entrance = exit)
a = $\lambda F/D$
λ = wavelength
F = focal length of monochromator collimator
D = aperture = $W \cos\theta$ (where W is the grating width)
x = coordinate in image plane

The image intensity distributions for several slit widths are shown on Figure 3.3.5.1. It is noted that, for a slit of infinitesimal width, most of the intensity change occurs over an interval substantially equal to the half width, a, of the diffraction pattern and the total width of the half intensity points is also approximately equal to a. For wider slits the half intensity point is located at approximately $x \sim S/2$ on the total width $2x \sim S$.

*P.H. van Cittert, Z. Physik 65, 547 (1930).

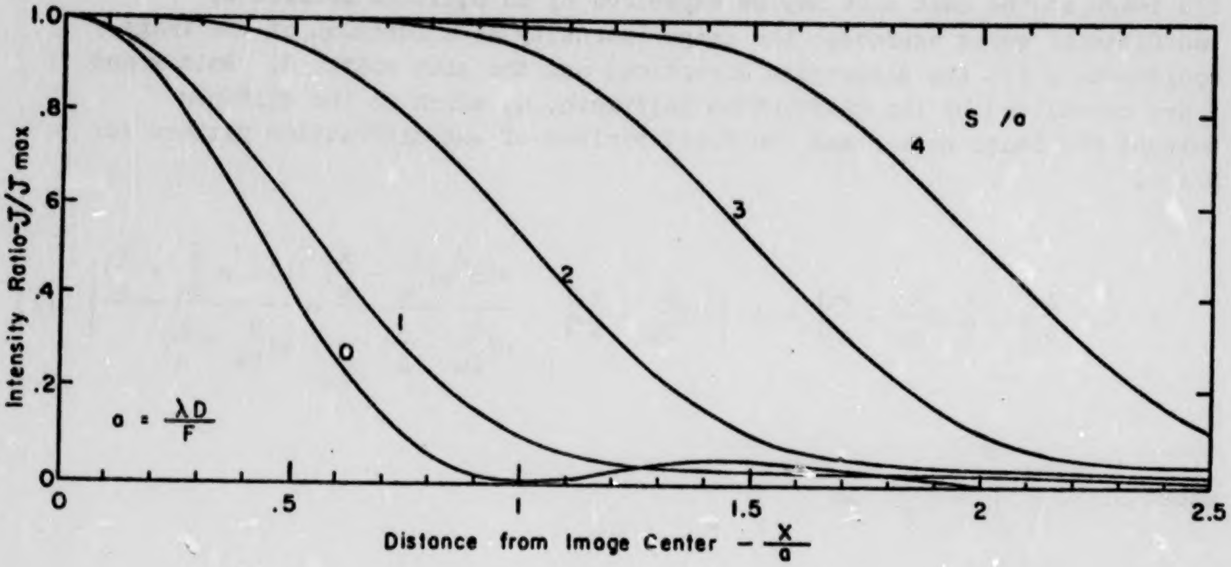


Figure 3.3.5.1 Image Intensity Distribution

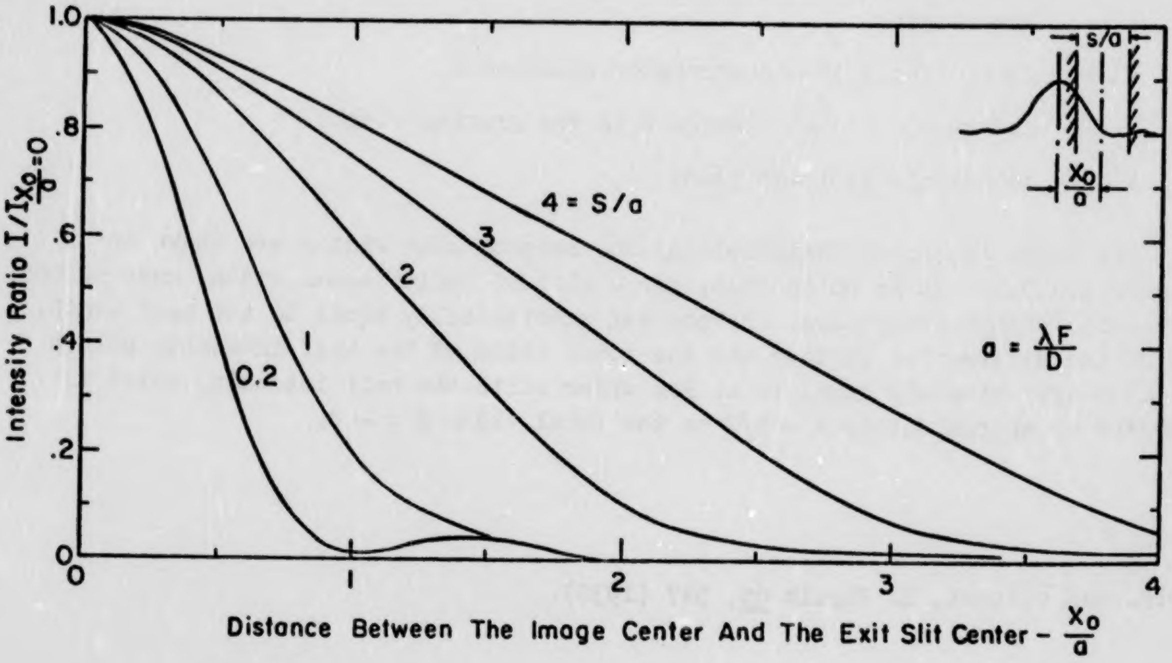


Figure 3.3.5.2 Integrated Output Intensity Distribution

Image intensity distributions such as those shown in Figure 3.3.5.1 have been integrated on a digital computer over an interval equal to that of the slit which produced the image. The resulting integrated output intensity distributions for several slit widths are shown on Figure 3.3.5.2 as a function of displacement, x_o, of the center of the image from the center of the exit slit. It is noted that the half intensity points are located at x_o slightly more than S/2.

The total width between half intensity points would therefore be slightly more than S. In the absence of diffraction one would expect from geometry that the total width between the half intensity points would be exactly equal to S.

Therefore, one may consider the total width, 2 x_o, to be composed of two parts: a geometrical component, $2 x_g = S$, and a diffraction component, $2 x_d = F(S/a)a$.

$$2 x_o = 2 x_g + 2 x_d = S + F(S/a)a$$

$$\text{or} \quad \frac{x_o}{a} = \frac{S}{2a} + \frac{F(S/a)}{2}$$

F(S/a) is defined as the diffraction contribution function and was obtained by subtraction:

$$F(S/a) = 2\left(\frac{x_o}{a} - \frac{S}{2a}\right).$$

This function is shown on Figure 3.3.5.3.

The spectral slit width is defined as the spectral interval corresponding to the total width of the output distribution at the half intensity points.

$$\Delta\lambda = 2x_o \left(\frac{d\lambda}{dx}\right)$$

$$\text{or} \quad \Delta\nu = 2x_o \left(\frac{d\nu}{dx}\right)$$

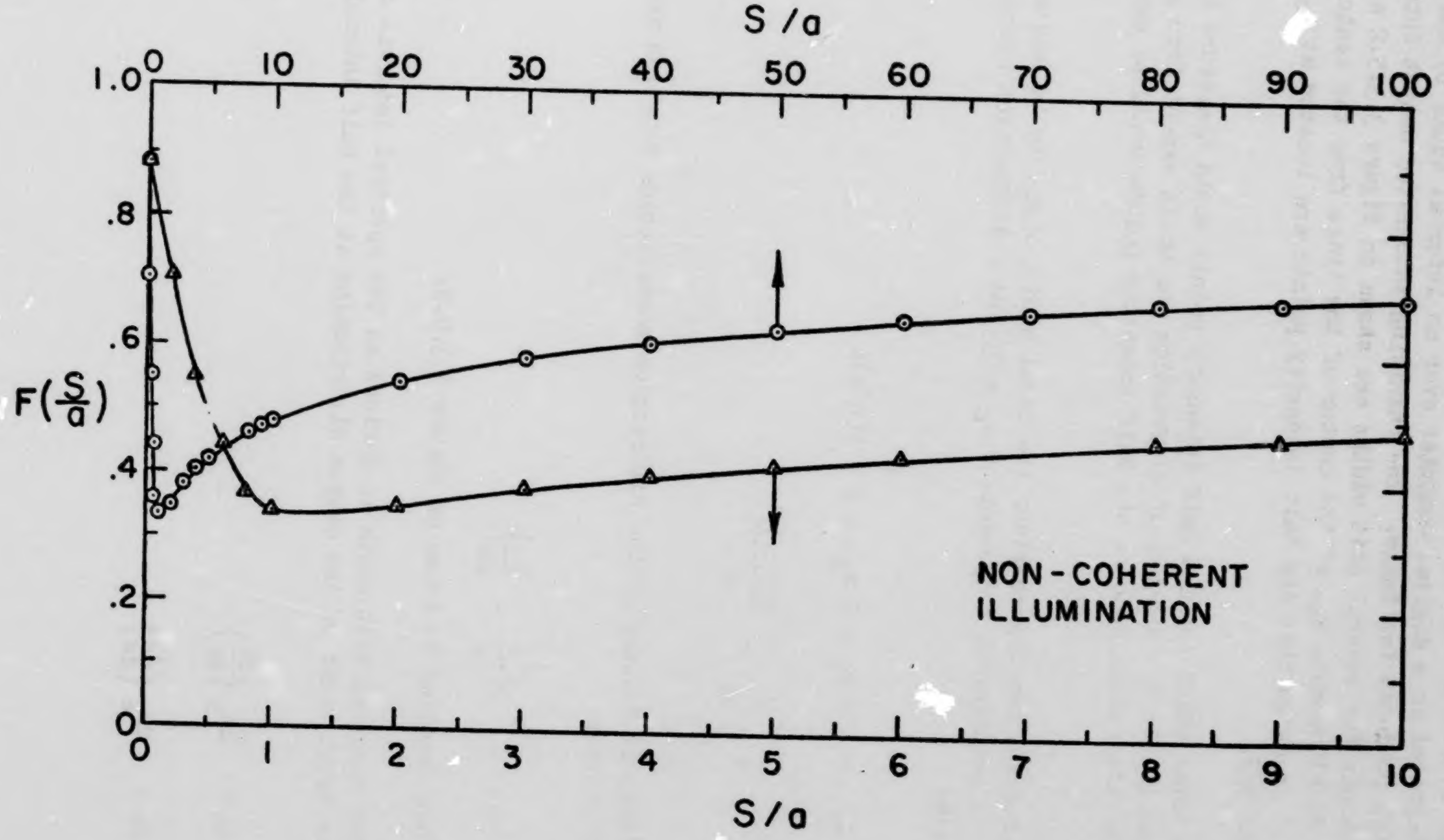


Figure 3.3.5.3 Diffraction Contribution Function

$$\Delta \lambda = (S + F\,(S/a)\,a)\,(d\lambda/dx)$$

$$\Delta \nu = (S + F\,(S/a)\,a)\,(d\nu/dx)$$

The grating equation is used to find the grating angle, θ , between the grating normal and the bisector of the incident and return beams (separated by an angle of $2\phi = 5$ degrees, i.e., $\phi = 2.5$ degrees; see Figure 3.4.4.1).

$$\begin{aligned} n\lambda &= A\,(\sin i + \sin r) \\ &= A\left[\sin(\theta + \phi) \pm \sin(\theta - \phi)\right] \\ &= A\left[\sin\theta\cos\phi + \cos\theta\sin\phi \pm \sin\theta\cos\phi - \cos\theta\sin\phi\right] \end{aligned}$$

If $n \geq 1$ the positive sign is used.

$$n\lambda = 2A\sin\theta\cos\phi$$

$$\sin\theta = \frac{n\lambda}{2\cos\phi}$$

The angle of the return beam is simply

$$r = \theta - \phi$$

Differentiation of the grating equation

$$n\Lambda = A(\text{Sin } i \pm \sin r)$$

with i = Constant gives

$$\frac{d\lambda}{dr} = A\cos r$$

and with $dx = F\,dr$

$$\frac{d\lambda}{dx} = \frac{A\cos r}{F}$$

Calculations have been made of the spectral slit width for both wavelength and wavenumber units and the results are shown on Figure 3.3.5.4.

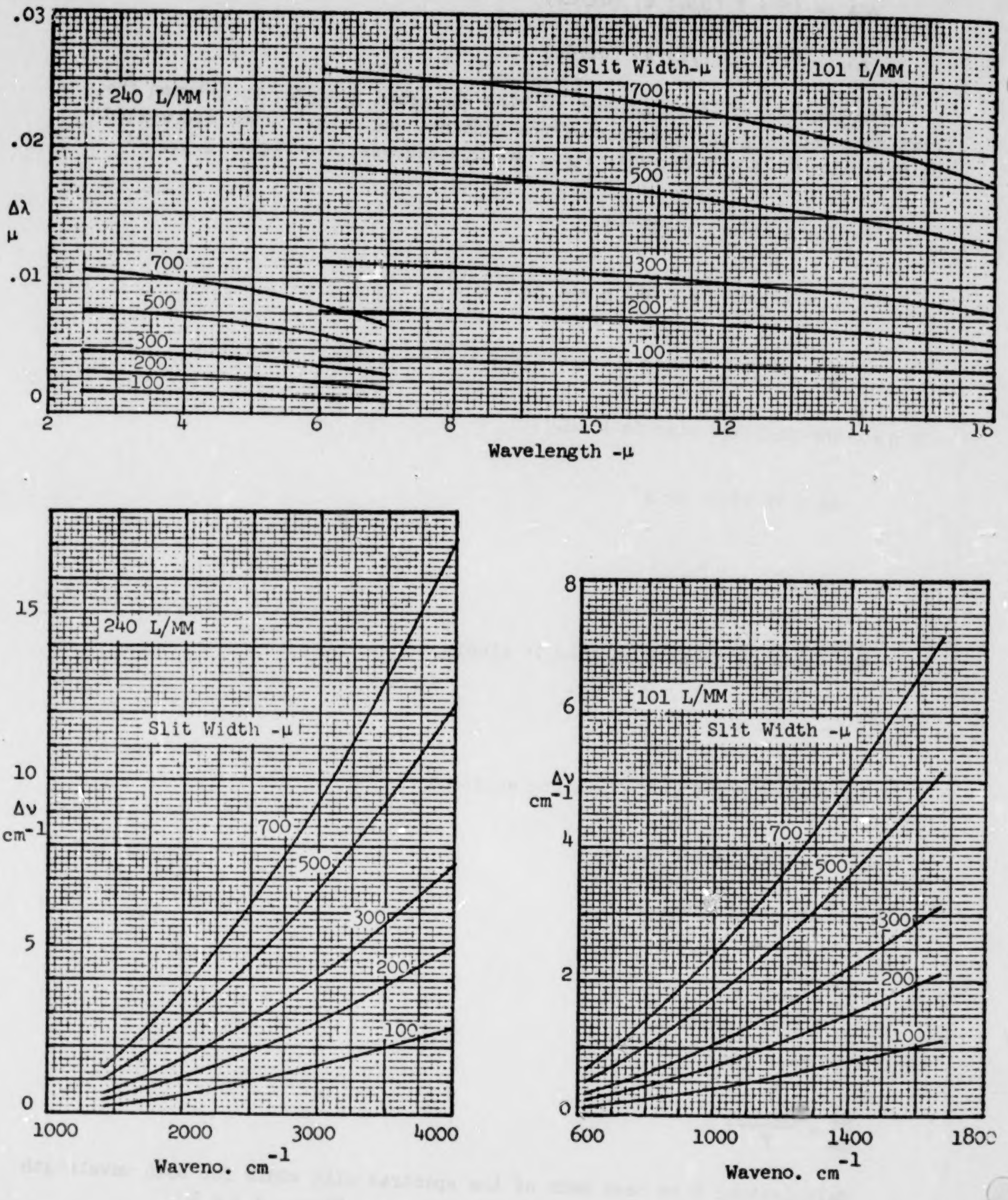


Figure 3.3.5.4 Spectral Slit Width

The parameter dν/ds is of interest when s is considered as a variable in the analysis of signal to noise ratio. Let $\Delta\nu_a$ be the value of Δν when s = 0.

$$\Delta\nu_a = (d\nu/dx)_g a$$

$$\frac{\Delta\nu}{\Delta\nu_a} \equiv R = \frac{s}{a} + F(s/a)$$

$$dR = d(s/a) + d(F(s/a))$$

$$\frac{dR}{d(s/a)} = 1 + \frac{d(F(s/a))}{d(s/a)}$$

$$= \frac{dR}{ds/a} = \frac{d(\Delta\nu)}{(d\nu/dx)_g a(ds/a)}$$

$$\frac{d\nu}{ds} = \left(\frac{d\nu}{dx}\right)_g \left[1 + \frac{d(F(s/a))}{d(s/a)}\right]$$

When s >> a, $d\nu/ds \approx (d\nu/dx)_g$; i.e., the value from the grating equation. When s = 0 $d(F(s/a))/d(s/a) = -1.00$ and $d\nu/ds = 0$.

3.4 OPTICAL SYSTEM DESIGN

The optical system consists of the following subsystems in the approximate order in which they occur along the optical path:

Blackbodies
Telescopes
Reference Optics
Monochromator
Detector Optics
Detector
Synch Systems

The arrangement of these subsystems is shown on Figure 3.4.1 for the transmission mode; for the emission mode the same arrangement is used except that the source blackbody and telescope are replaced by the emitting source.

It may be helpful to review the system description in Section 3.2 using Figure 3.2.1.

Each of the above subsystems will be discussed in the following sections with emphasis on characteristics related to system performance.

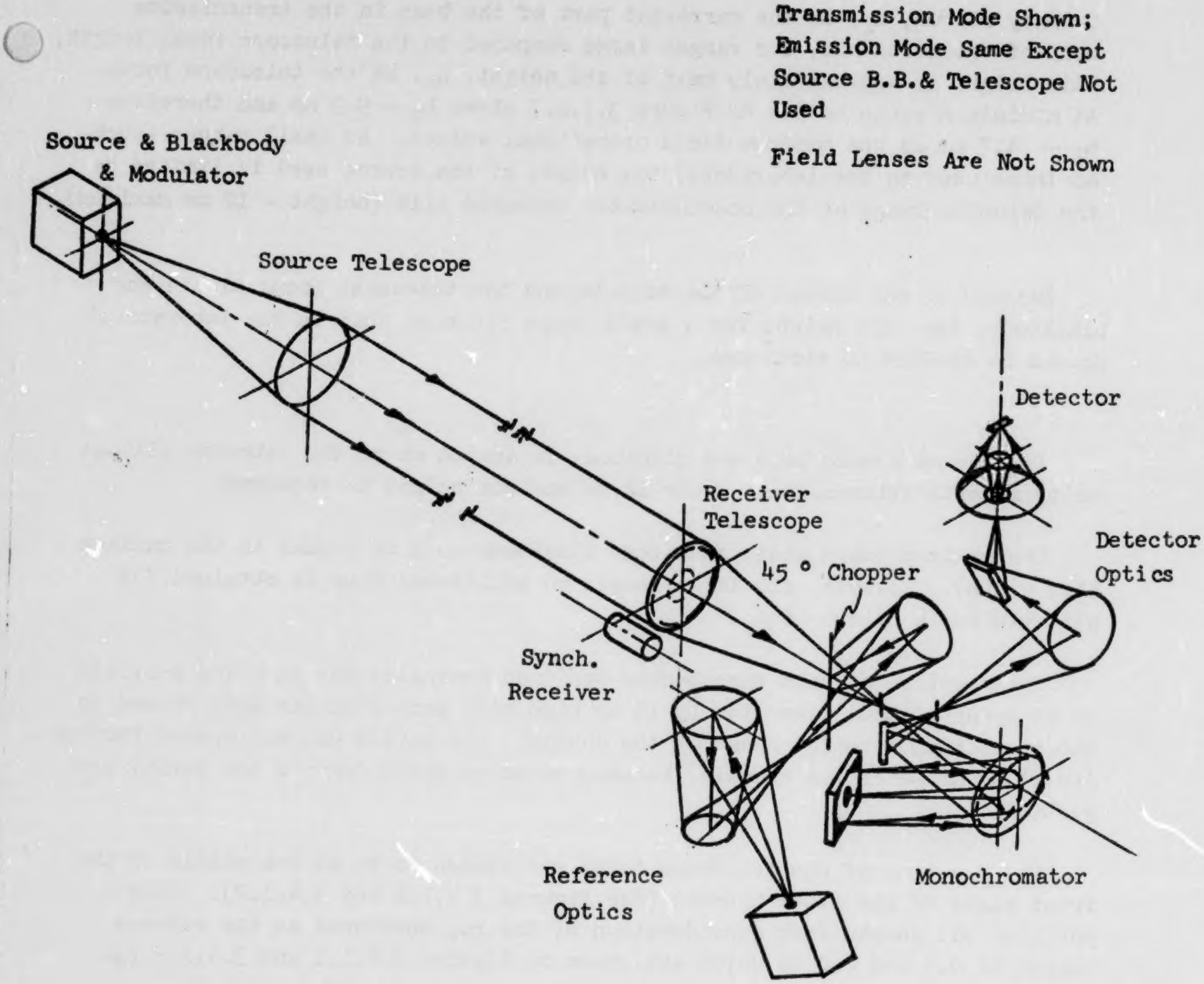
3.4.1 Blackbodies

The blackbodies serve as sources of radiant energy for the system which have known spectral characteristics. Since no other source has a spectral distribution as well known as that of a blackbody no alternatives were considered. In order to obtain a high signal a high temperature blackbody is desired. Although there are a number of suppliers of blackbodies for temperature around 1000 to 1200°K only one, namely Electro Optical Industries, makes a blackbody which operates at significantly higher temperatures. One having a maximum temperature of 1900°K was selected for use in this system; an operational temperature of 1800°K was selected for increased lifetime over that at 1900°K.

The temperature of the blackbody is controlled by a sensor mounted on the front plate of the outer housing which activates an electronic control system.

The blackbody housing is cooled by a closed cycle glycol cooling system.

The aperture size was selected to be equal or larger than the system pupils nearest the blackbody aperture.



Transmission Mode Shown; Emission Mode Same Except Source B.B. & Telescope Not Used

Field Lenses Are Not Shown

Figure 3.4.1 Optical System Schematic

No Scale

From Figure 3.3.2.2 it may be noted that the image height of the remote primary mirror, h_1, is the narrowest part of the beam in the transmission mode of operation and, for ranges large compared to the telescope focal length, this height is approximately half of the height, h_o, at the telescope focus. At a minimum range of 0.4 km Figure 3.3.2.7 gives $h_o \sim 9.3$ mm and therefore $h_1 \sim 4.7$ mm as the maximum field operational values. At small ranges (such as those used in the laboratory) the height of the source used is limited by the detector image at the monochromator entrance slit (height = 12 mm maximum).

Because of the spread of the beam beyond the telescope focus within the blackbody, the slit height for a small range (such as that in the laboratory) should be limited to about 8mm.

For the reference beam the blackbody is imaged on to the entrance slit at unity magnification so that again 12 mm maximum height is required.

The maximum image width at either blackbody is 2 mm (equal to the maximum slit width). However, for large ranges no additional flux is obtained for slit widths in excess of h_o.

The aperture of both blackbodies was made nominally the same and consists of an opening about 6 mm wide by 13 mm high with semi-circular ends formed in the insulating material ahead of the cavity. The cavity was not opened further (to 13 mm diameter for example) because to do so would degrade the cavity properties.

The position of the telescope focus was chosen to be at the middle of the front plate of the outer housing (see Figures 3.4.1.1 and 3.4.1.2). This position was chosen from consideration of the ray envelopes at the extreme ranges of 0.4 and 4.0 km which are shown on Figures 3.4.1.1 and 3.4.1.2 respectively.

3.4.2 Telescopes

Large telescopes are necessary to maintain system throughput or etendue for the large ranges specified for the present system. The maximum mirror size (clear aperture) was specified as 24 inches or less. This size permits an overall telescope diameter of 28 inches which will pass through ordinary doorways.

The telescope focal length was established by considering the characteristics of the monochromator (particularly the grating size and collimator focal length), the variation of telescope obscuration with f/number and the effects of double diffraction in the monochromator. A focal length of 120 inches (3048 mm) was chosen making the overall telescope f/no. = 5.

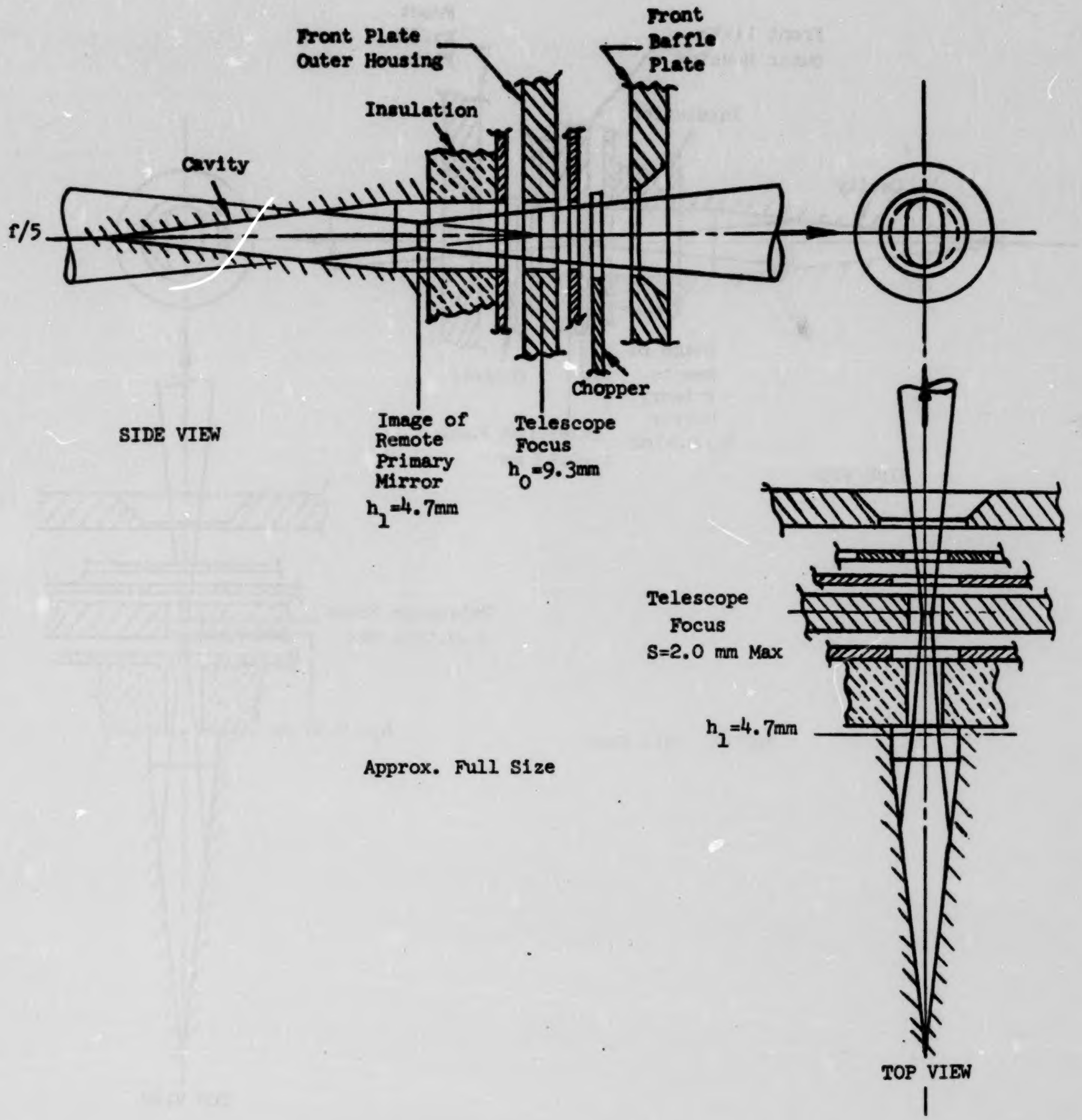


Figure 3.4.1.1 Source Blackbody and Ray Envelope; Range=0.4KM

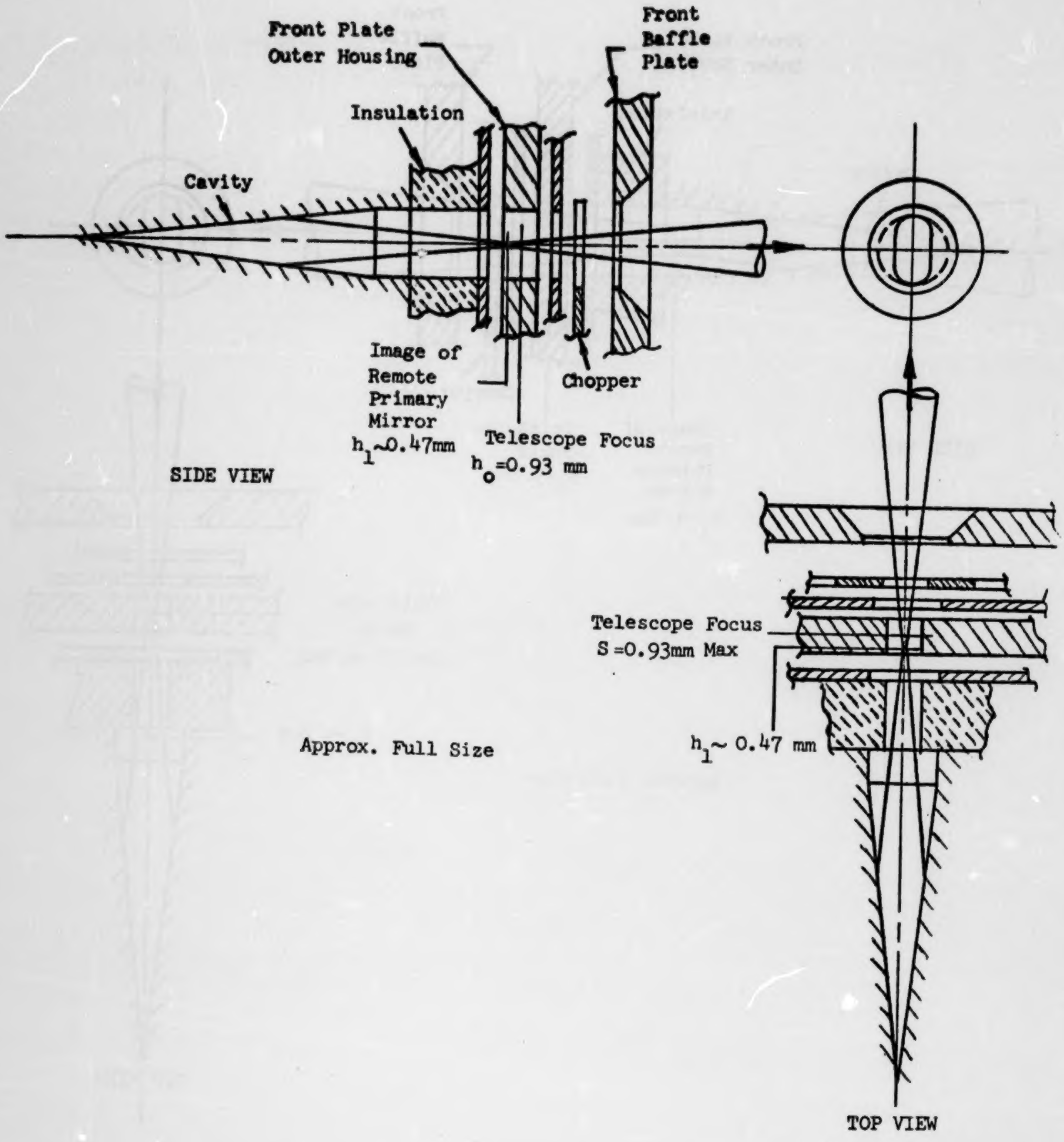


Figure 3.4.1.2 Source Blackbody and Ray Envelope; Range = 4.0KM

In order to obtain portability and a compact design, a two mirror telescope design is necessary consisting of a concave primary mirror and a convex secondary mirror. Several combinations of mirror surface forms were considered. These are listed below in order of performance and difficulty of construction.

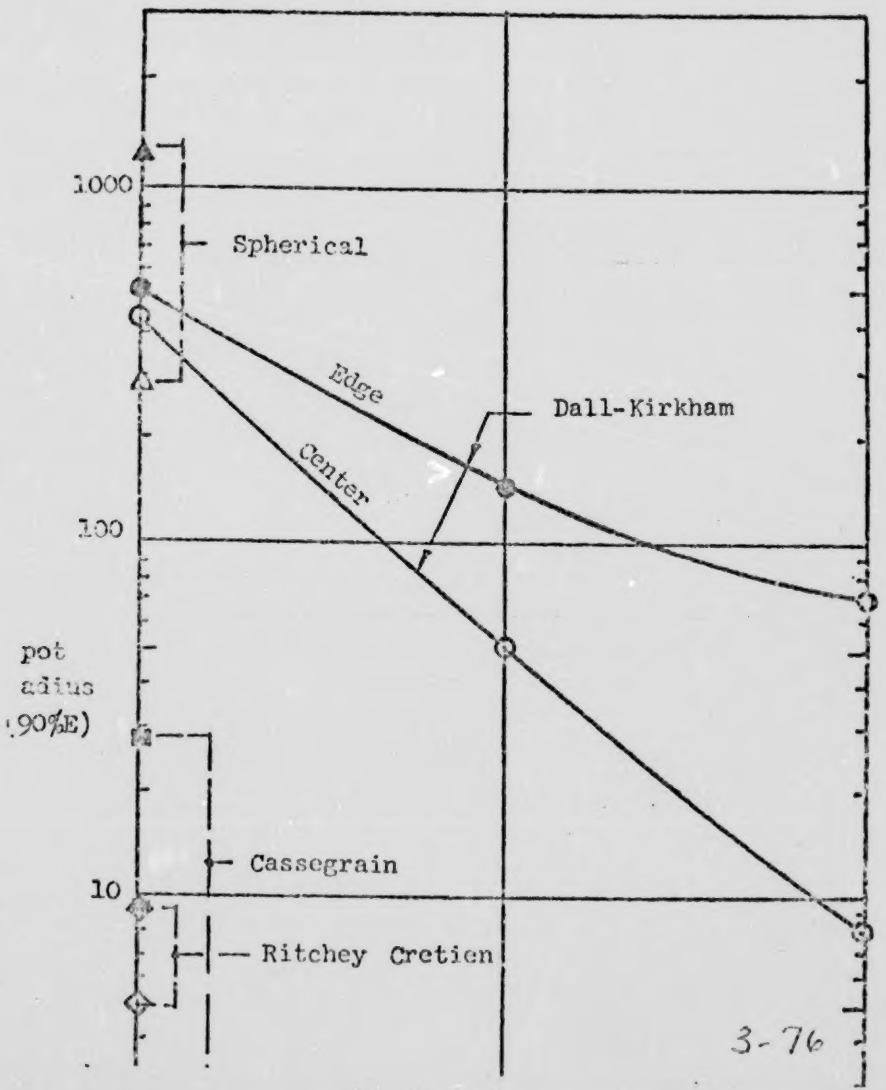
Type	Primary Mirror	Secondary Mirror
Spherical	Spherical	Spherical
Dall Kirkham	Elliptical	Spherical
Cassegrain	Paraboloidal	Hyperboloidal
Ritchey Chretien	Hyperboloidal	Hyperboloidal

Calculations of the performance of these designs (for a f/1.0 primary mirror) were made using the IBM computer "Program for Optical System Design" (or POSD). Spot diagrams were made using 100 rays and the size of the spot size which contained 90% of the energy was determined. Calculations were made on-axis and at the edge of a 0.25° total field of view. The results of these calculations are shown on Figure 3.4.2.1 by means of open and solid symbols respectively.

Calculations were also made for the Dall Kirkham design with f/1.5 and f/2.0 primary mirrors and these results are also shown on Figure 3.4.2.1.

A criterion of performance is needed with which to compare the above data. The radius of the first dark ring of a diffraction pattern of a circular aperture is approximately $\lambda F/D = \lambda$ (f/no) which, at the longest wavelength of 13.5 microns and f/5, would give a diffraction pattern radius of about 67 microns or a diameter of 135 microns (within which about 84% of the energy lies). A criterion of 150 micron diameter for 90% of the energy was adopted (to be evaluated at a wavelength in the visible range).

An important telescope design parameter is the ratio of the overall focal length to the primary mirror focal length; $m = F/F_1$. If the primary mirror diameter, D, is taken as a controlling aperture this ratio can also be expressed as $m = (D/F_1)/(D/F)$ = (primary f/no)/(overall f/no). Large values of m allow a short telescope but increase the aberrations of the system. Three values of m were used in the evaluations as shown in the following list.


1000
100
10
pot
adius
.90%E)
Spherical
Edge
Center
Dall-Kirkham
Cassegrain
Ritchey Cretien

m	F_1	Pri. f/no	Telescope Length
5	24 in.	1.0	23.5 in.
3.33	36	1.5	30.23
2.5	48	2.0	36.0

The overall telescope lengths include an arbitrary 3 inches at each end for structure and the assumption is made that the telescope focus is 12 inches beyond the end of the telescope. Figure 3.4.2.2 shows a comparison of these three f/5 telescope designs (F = 120 and D = 24 inches).

In order to achieve the desired spot diameter of 150 microns it would be necessary to use the Ritchey-Chretien design with a primary mirror f/no = 1.0 whereas at a primary mirror f/no = 2.0 a Dall Kirkham design would be acceptable. Because the primary mirror of the Dall Kirkham design is shallower less material has to be removed; also the departure from a sphere is substantially less (approximately 15 times less). Testing of the Dall Kirkham components is also easier. Therefore, the increased length of the f/2.0 primary mirror Dall Kirkham design was accepted in order to permit the easier and less costly construction and testing compared to the f/1.0 Cassegrain or Ritchey Chretien design.

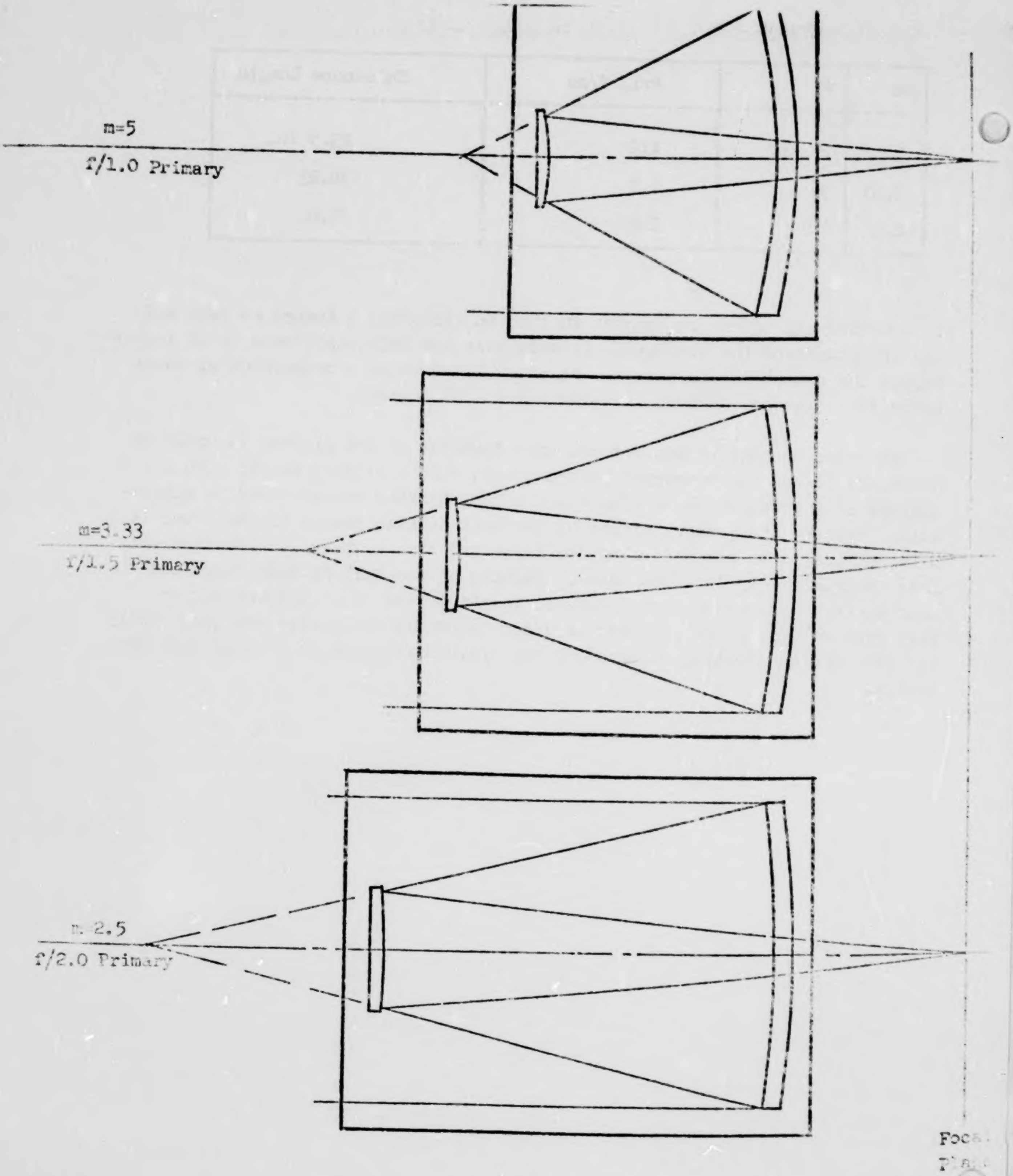


Figure 3.4.2.2 Telescope Length Comparison

3.4.3 Reference Optics

The purpose of the reference optical system is to provide a reference beam; i.e., a beam to be compared with that received from the receiver telescope. The reference optical system contains four reflecting surfaces; the same number as in the source beam for the transmission mode of operation. The components of the reference optical system (in the direction of flux) are:

Reference blackbody
Spherical mirror
Flat mirror
Toroidal mirror
Reference chopper

The reference blackbody is nominally identical to that used for the source beam (see Section 3.4.1) except that no chopper is employed.

The spherical mirror forms an image of the blackbody (nominally unity magnification) at an intermediate focus via the flat mirror.

The toroidal mirror forms an image of the intermediate focus (again nominally unity magnification) at the monochromator entrance slit via the reference chopper. The toroid (60° off-axis) was used to reduce aberrations resulting from the large off-axis angle.

The reference chopper has three blades which are polished and aluminized on the side nearest the monochromator. It is set at roughly 45° so as to reflect the reference beam on to the entrance slit when a blade is in position and to pass the source beam to the entrance slit when a slot is in position.

The major optical design problem was that of finding the proper positions of the elements subject to the mechanical constraints of sturdy and convenient element mountings, clearance of the beam by structural elements and enclosure of the system elements for protection.

Provision is made at the intermediate focus for inserting either a blocking slide or a mercury lamp.

3.4.4 Monochromator

The key choice in the optical system design is the means of dispersion since pollution detection was specified to be by spectral examination of the data; i.e., pollutants are to be identified by their spectral location and character and the amount of pollutant is to be measured by the depth of absorption or emission. The interferometer gives the highest system performance but requires real-time data conversion by Fourier transformation in order to meet the specified real-time data display. At the time this system was proposed no acceptable data conversion system was available. The alternative dispersing element chosen was a grating monochromator. In the infrared region of interest prism monochromators have lower luminosity and filter discs do not have the specified resolution of about 0.01 micron. A survey of many manufacturers of grating monochromators revealed that there was only one commercially available instrument having the specified linear wavenumber drive, namely the Perkin Elmer Model 210, which was chosen as the dispersive component. The alternative of building a grating monochromator was considered to be uneconomical.

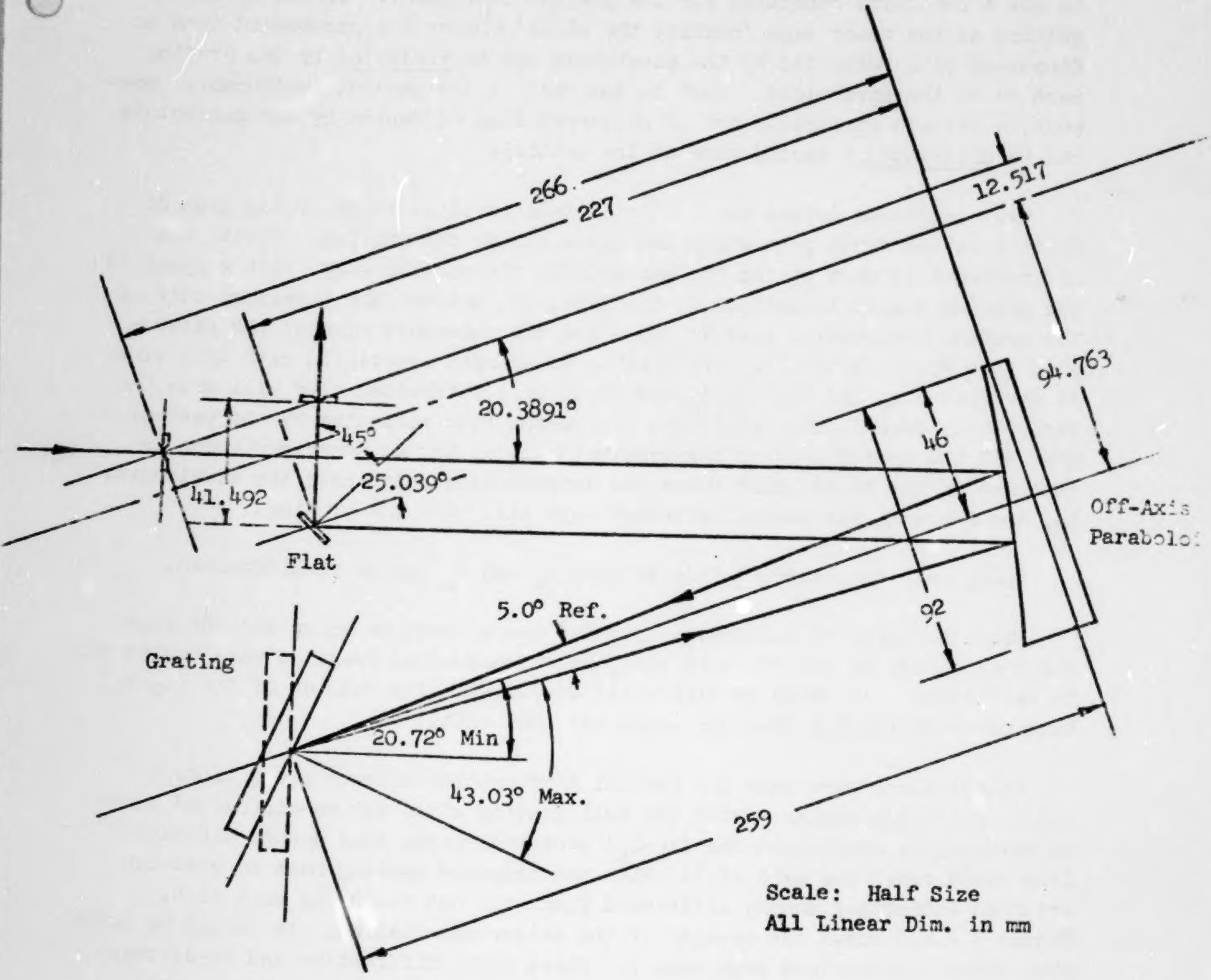
The optical design of the monochromator had to be obtained from measurements since no optical layout could be obtained from the manufacturer even though exhaustive requests were made. The precision of these measurements was limited because of a desire not to disturb the monochromator alignment. Since computer runs were to be made using these data the measurements were adjusted for internal consistency and Figure 3.4.4.1 shows the adjusted values used for analysis.

Double Diffraction

A mask about 25 mm wide placed along the outside vertical edge of the paraboloidal mirror by the manufacturer was removed since it severely restricts the useful aperture. The purpose of the mask according to the monochromator manual was to eliminate double diffraction. Double diffraction occurs when flux strikes the grating twice in its path through the monochromator. From the geometry it was apparently designed by the criterion set forth by Chupp and Grantz* which states that a normal to the collimator surface at the outermost point on the collimator should miss the grating.

---

*V. L. Chupp and P. C. Grantz, Appl. Optics 8 925 (1969).



Note: Precision of Measurements ~ 0.5 to 1 mm; Values Adjusted for Internal Consistency

Figure 3.4.4.1 Monochromator Optical Diagram

This criterion is a sufficient condition to prevent double diffraction but is not a necessary condition for the present instrument. If the normal to the grating at the inner edge (nearest the slits) misses the paraboloid then no dispersed flux reflected by the paraboloid can be reflected by the grating back on to the paraboloid. Such is the case in the present instrument. However, a certain spectral range of dispersed flux reflected by the paraboloid can be diffracted a second time at the grating.

Two conditions define the limits of this spectral range of the flux diffracted on the first pass which can again strike the grating. First, the diffracted flux must strike the paraboloid; the minimum slope with respect to the grating normal is defined by the line, AB, between the innermost edge of the grating (or grating mask if used) and the outermost edge of the paraboloid (see Figure 3.4.4.2). The minimum wavelength associated with this slope is designated λ_p and for $\lambda < \lambda_p$ the first pass diffracted flux will miss the paraboloid; second, the first pass diffracted flux reflected by the paraboloid must hit the useful part of the grating; a line, AB, as described above is extended to the focal plane where the intersection represents the wavelength, λ_g, and for $\lambda < \lambda_g$ the second reflected rays will miss the grating.

Thus, only the incident flux between λ_p and λ_g can be re-diffracted.

With the range of incident slopes for re-diffraction known and the known slope necessary to hit the exit slit, the corresponding range of wavelengths can be calculated. If these re-diffracted wavelengths lie outside of the $(\lambda_p - \lambda_g)$ band no re-diffracted flux can reach the exit slit.

Calculations were made for the 101 L/MM grating which has the largest range of grating angles. With the full grating width the re-diffracted range of wavelengths overlapped the $(\lambda_p - \lambda_g)$ band indicating that doubly diffracted flux could reach the exit slit. With the proposed grating mask no over-lap occurred indicating doubly diffracted flux will not reach the exit slit. Figure 3.4.4.3 shows the results of the latter calculation. It should be noted that these calculations were made for first order diffraction and re-diffraction since a long wavelength pass filter eliminates flux at higher orders. As stated before, zero order flux misses the paraboloid and therefore does not reach the exit slit.

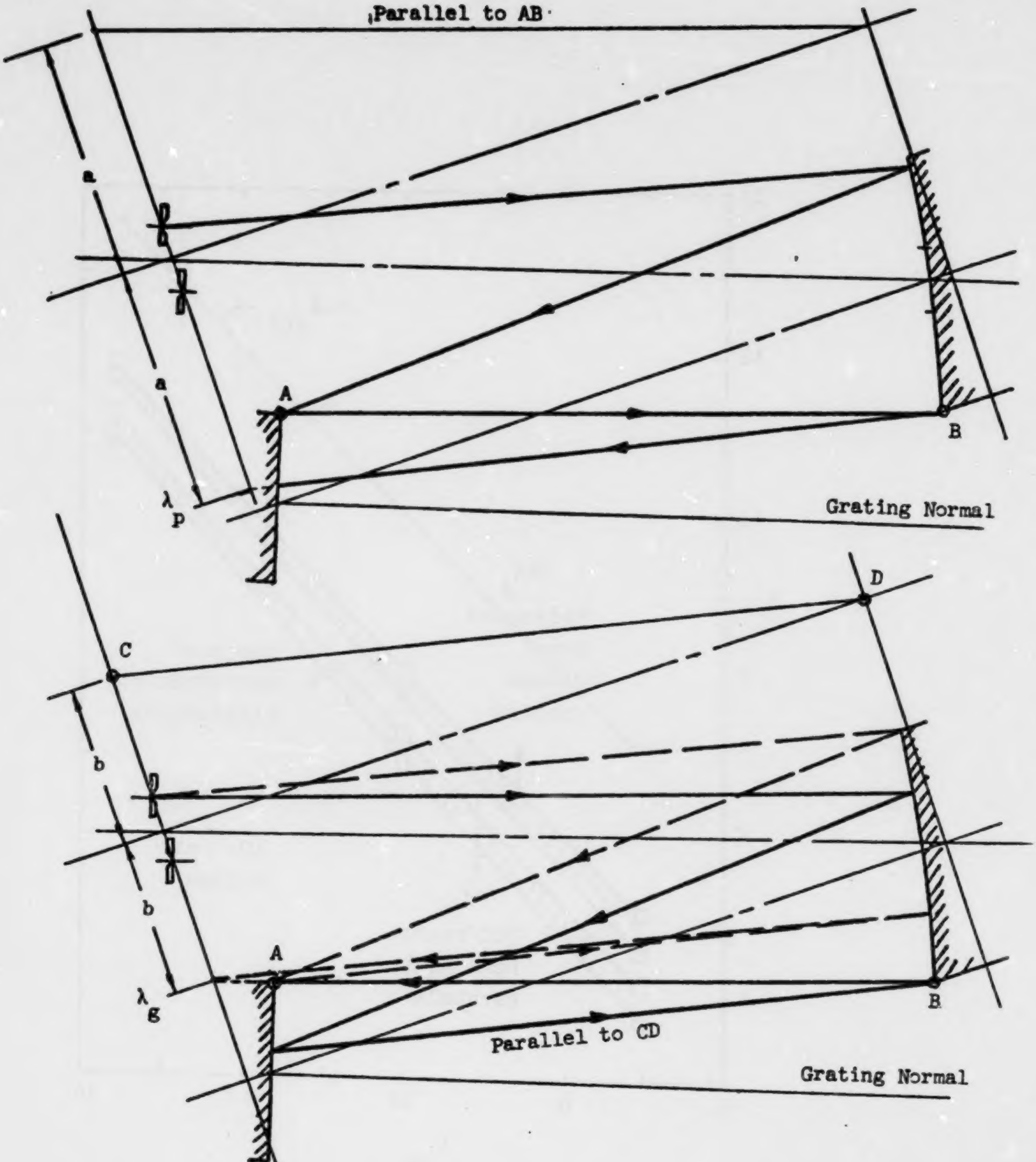
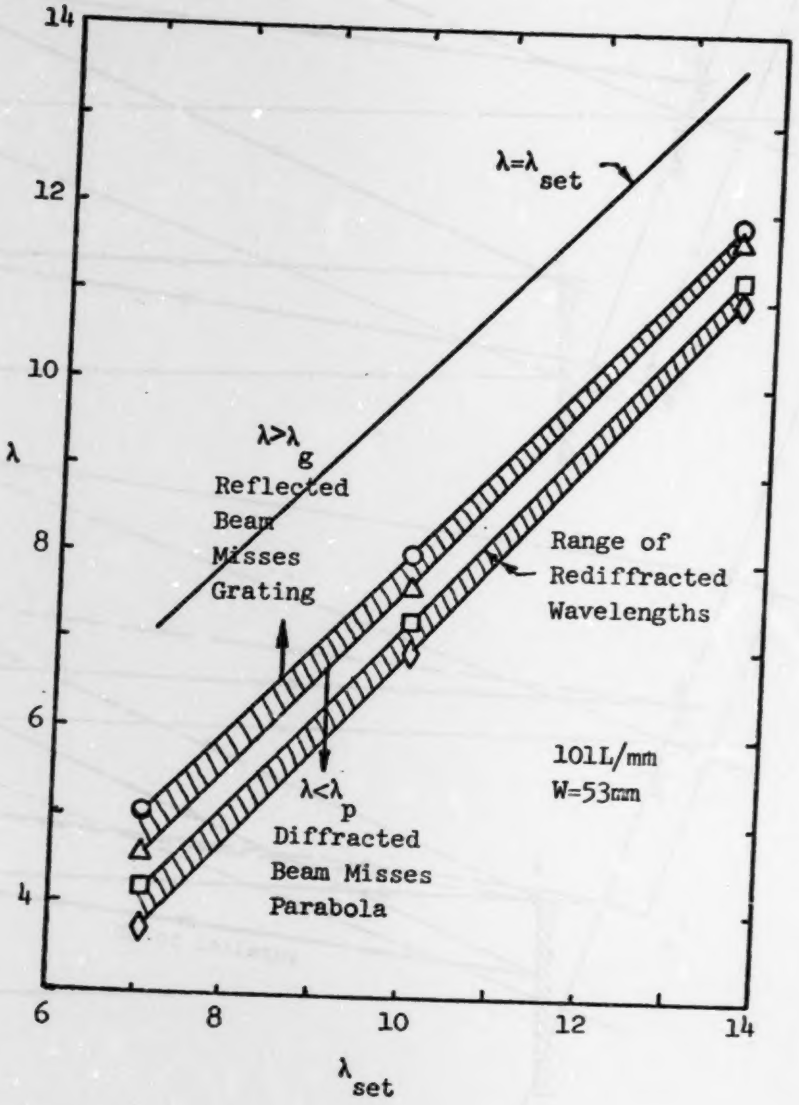


Figure 3.4.2.2 Double Diffraction Limiting Incident Rays



Note: Since the bands do not overlap there is no double diffraction

Figure 3.4.4.3 Double Diffraction Wavelength Ranges

The fact that there is a gap between the bands of Figure 3.4.4.3 indicates that a slightly wider grating mask could have been used. The 53 mm width chosen is therefore slightly conservative to allow for possible calculation and measurement errors.

Grating Mask

One of the system apertures is located at the monochromator grating (the other is at the entrance slit). There are two ways in which the aperture may be accomplished: 1) the beam can completely cover the grating and the rectangular grating boundary can form the aperture, or 2) the beam can fall entirely within the grating boundary and a mask on the grating is made slightly more restrictive than the beam. The latter method was chosen because a larger area could be obtained and because of double diffraction described above. Completely covering the grating would require very fast optics throughout the system (about f/3.3), a larger central obscuration in the telescope and difficulty in maintaining the low f/number where the beam must be turned (in the detector optics, for example).

The outer limit of the mask is made circular to nearly match the telescope beam outer boundary for the minimum grating angle of 20.72°. The width of the beam along the face of the grating for this condition is

$$\begin{aligned} W &= D(F_c/F)(\cos 20.39^\circ/\cos 20.72^\circ) \\ &= 610(266/3048)(.937/.935) \\ &= 53.3 \text{ mm} \end{aligned}$$

where D and F are the diameter and focal length of the telescope respectively and F_c is the monochromator callimator focal length (all in mm). The beam height $H = D(F_c/F)$ is 53.2 mm. An outer mask diameter of 52.8 mm was chosen to allow for alignment variations.

The inner limit of the mask is made elliptical to nearly match the telescope beam obscuration at the maximum grating angle of 43.03°. The width of the beam obscuration along the face of the grating is

$$\begin{aligned} W' &= D'(F_c/F)(\cos 20.39/\cos 43.03^\circ) \\ &= 254(266/3048)(.937/.731) \\ &= 28.4 \text{ mm} \end{aligned}$$

where D' is the telescope obscuration diameter in mm. The height is $H' = D'(F_c/F) = 22.2$ mm. An ellipse 29.4 wide by 23.2 mm high was chosen to cover the telescope obscuration.

The central mask area is supported by vertical strips 2mm wide in the center of the mask. The calculated nominal grating mask open area is 15.9 cm^2.

Entrance Slit

In order to control the aperture at the entrance slit it is necessary to add a slit height control. A bi-lateral system is used under control of a direct reading 0-13 mm micrometer. In the transmission mode of operation this slit height would normally be set to the value of h_o for the particular range of the set-up (see Figure 3.3.2.7) for maximum energy. For the emission mode of operation a value of about 12 mm should be used so as to fill the detector; (i.e., 2 mm x 6). In the laboratory a maximum of about 8 mm should be used (based on the ray envelope beyond the focus at the source blackbody just filling the source cavity).

In the transmission mode of operation a larger slit height than h_o may be used to reduce the effects of atmospheric refraction. In this case the value of τ_{sig} must be increased (or the relative source channel to reference channel gains increased) by the ratio of h/h_o to compensate for the larger reference signal.

3.4.5 Detector Optics

The purpose of the detector optics system is to form a reduced size image at the detector so that a smaller detector may be used. The reduction factor used by the monochromator manufacturer of 6 times was used here also (on-axis ellipse 5.326:1).

Several forms of detector optics were considered all based on systems presently in use:

1. 90° off-axis ellipse
2. On-axis ellipse
3. "Cassegrain" system

These three systems are illustrated on Figure 3.4.5.1.

In consideration of the space requirements it was decided that the dewar-cooler should be vertical. The 90° off-axis would therefore be ideal since only one reflecting surface would be required. The on-axis ellipse would require a diagonal to turn the beam and would require a stem mounted detector so as not to block the beam. In the "Cassegrain" system the reduction is made in two steps: a 2 times reduction by a toroid followed by the 3 times reduction in the two mirror "Cassegrain" assembly. The term "Cassegrain" is used here for brevity even though both mirror surfaces are spherical.

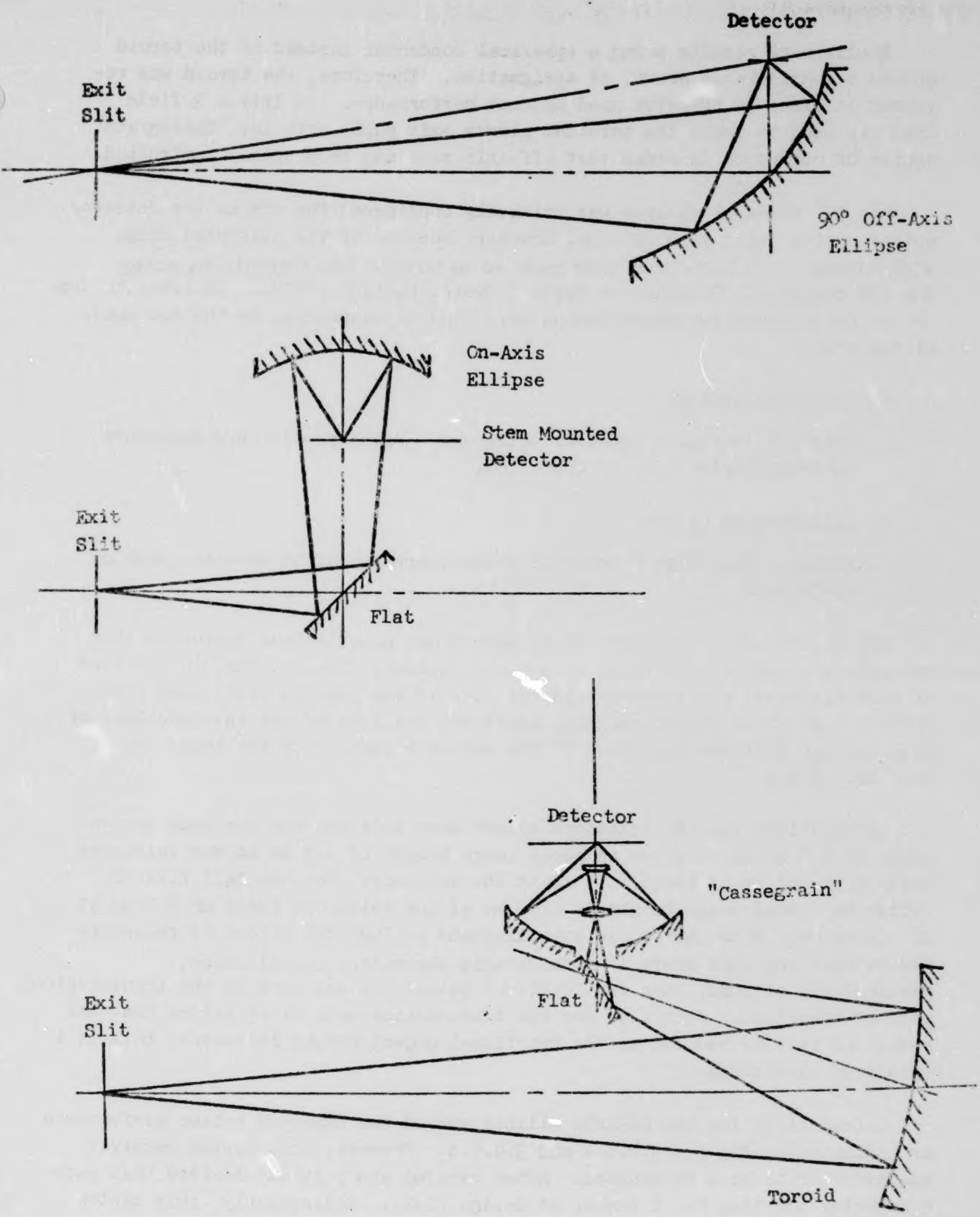


Figure 3.4.5.1 Detector Optical Systems

Preliminary results using a spherical condenser instead of the toroid showed a considerable amount of astigmatism. Therefore, the toroid was retained in order to preserve good optical performance. In Irtran 2 field lens was used to image the toroidal mirror exit pupil onto the "Cassegrain" center of curvature in order that off-axis rays may be properly controlled.

The 90° off-axis ellipse was initially considered for use as the detector optics system (with reservations, however, because of its suspected large aberrations). Calculations were made to determine the aberrations using the IBM computer, "Program for Optical System Design" (POSD). In order to show system performance two combinations were used corresponding to the two modes of operation.

1. Telescope System

   Source telescope + Receiver telescope + Detector Optics;corresponds to transmission mode of operation.

2. Dall-Kirkham System

   Receiver telescope + Detector Optics;corresponds to emission mode of operation.

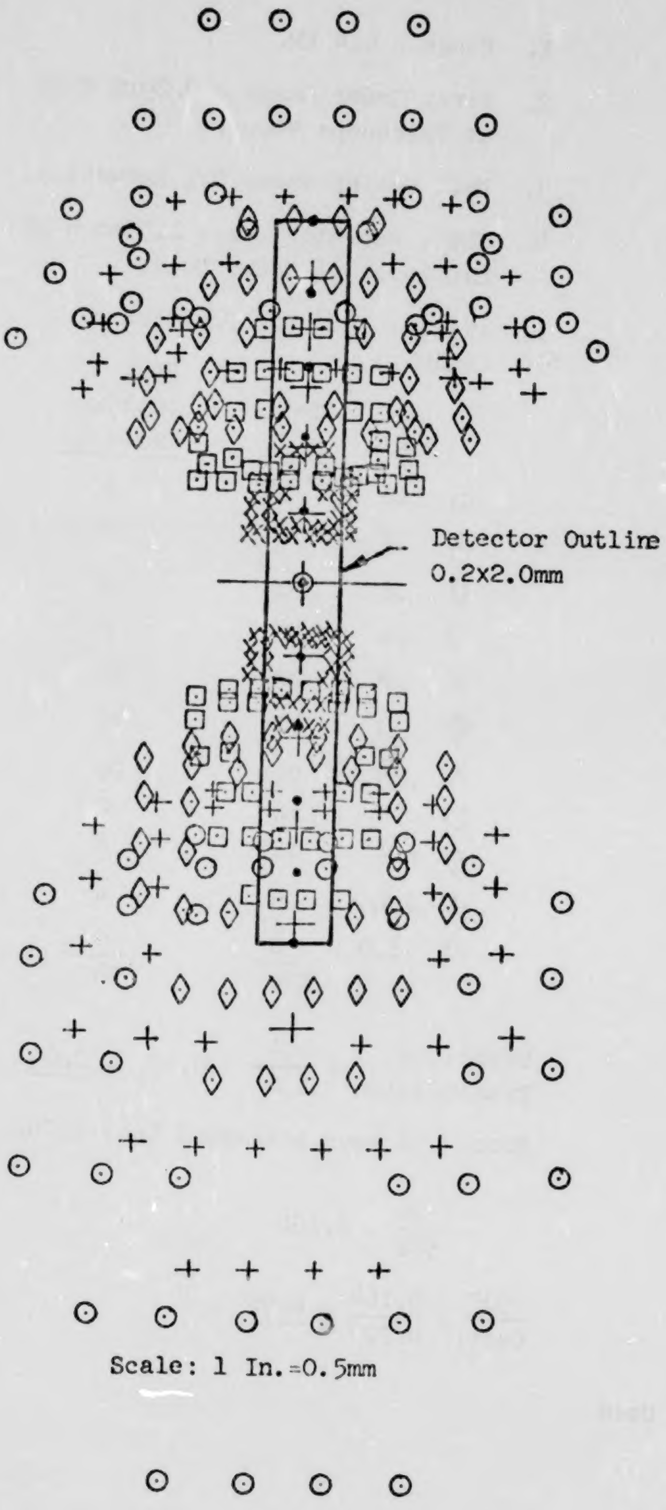
The monochromator was omitted to save time; calculations indicated that its omission had little effect on the aberrations. The results, in the form of spot diagrams, are shown on Figures 3.4.5.2 and 3.4.5.3 which show (for various fractional object heights, OBJH) the location of the intersections of rays through different portions of the entrance pupil with the image (or detector) plane.

Calculations for the telescope system were made for the shortest design range of 0.4 km which gives an ideal image height of 9.3 mm at the telescope focus or a height of about 1.55 mm at the detector. For the Dall Kirkham system the ideal image height is 12.0 mm at the telescope focus or 2.0 mm at the detector. Note that these spot diagrams include the effect of telescope aberrations and that there is considerable aberration cancellation, particularly of coma, when two identical telescopes are used in the transmission mode of operation. Note also for the transmission mode of operation that the number of rays is reduced as the fractional object height increases; this is a result of vignetting.

Calculations for the on-axis ellipse showed the expected better performance as indicated on Figures 3.4.5.4 and 3.4.5.5. However, this system requires the detector to be stem mounted. After careful study it was decided that such a detector mounting has a number of design risks. Consequently, this system was abandoned.

Data 6/14/70-6

1. **First Order Image 12mm High at Telescope Focus.**
2. **Ellipse Theo. 6:1.**
3. **Theo. Detector Image 2mm High; Clustered at Heavy Dots.**
4. **Crosses are Locations of Chief Ray.**
5. **40 Rays per OBJH Reach Detector Plane.**



	OBJH	Rays Hitting Detector
○	1.0	2
+	.8	2
◇	.6	4
□	.4	10
×	.2	32
⊕	0	40
×	-.2	32
□	-.4	10
◇	-.6	4
+	-.8	4
○	-1.0	4
		144

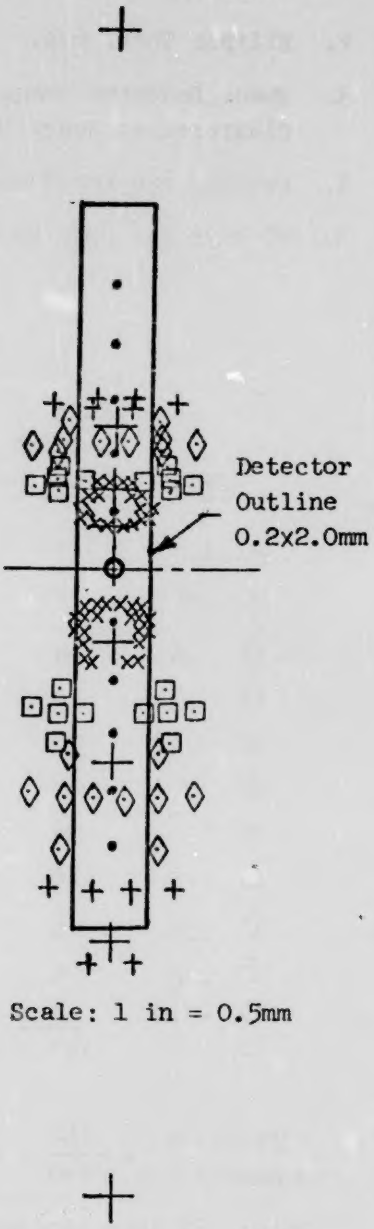
$$\text{Effective Transmission} = \frac{144}{440} = 0.32_7 \sim \underline{0.33}$$

Note: 52 Rays Attempted Each OBJH.

$$\frac{144}{572} = 0.252$$

$$\frac{90^\circ}{\text{Cass.}} = \frac{0.252}{0.629} = \underline{0.40}$$

Figure 3.4.5.2 Dall Kirkham + 90 Degree Ellipse



Scale: 1 in = 0.5mm

Note: Plotted Pattern Inverted
Because Neg. Object Height Used

Data 6/18/70-2

1. Range = 0.4 KM.
2. First Order Image = 9.29mm High at Telescope Focus.
3. Det. Optics Theo. 6:1 Reduction.
4. Theo. Detector Image 1.55mm High Clustered at Heavy Dots.
5. Crosses Indicate Position of Chief Ray.

	OBJH	Total Rays	Rays Hitting Detector
○	1.0	0	2
+	.8	6	2
◊	.6	10	2
□	.4	10	2
×	.2	22	20
⊕	0	40	40
×	-.2	22	20
□	-.4	10	2
◊	-.6	10	2
+	-.8	6	4
○	-1.0	0	0
		136	94

Effective Transmission $= \frac{94}{136} = 0.69_2 \sim \underline{0.69}$

Note: 52 Rays Attempted Each OBJH.

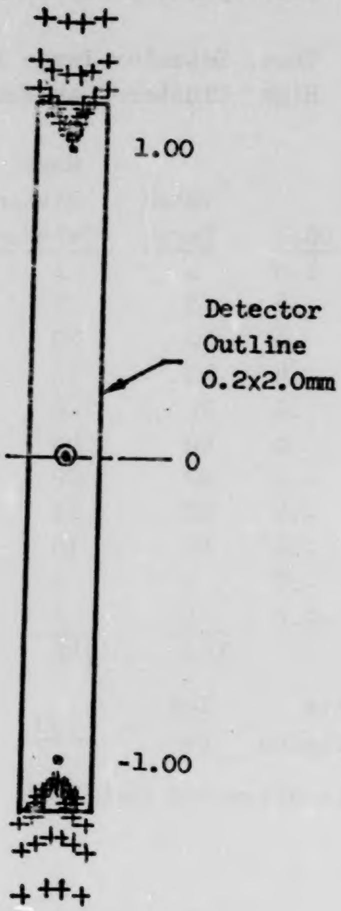
$$\frac{94}{572} = 0.164$$

$$\frac{90^\circ}{\text{Cass.}} = \frac{0.164}{0.227} \sim \underline{0.72}$$

Figure 3.4.5.3 Telescope System + 90 Deg. Ellipse

Data 1/25/70

1. Image 9.29 mm High at Telescope Focus
2. Det. Optics 5.326:1
3. Theo. Detector Image 1.74mm High;



Scale: 1 in = 0.5mm

	OBJH	Total Rays	Rays Hitting Detector
+	1.0	40	26
⊕	0	40	40
+	-1.0	40	26

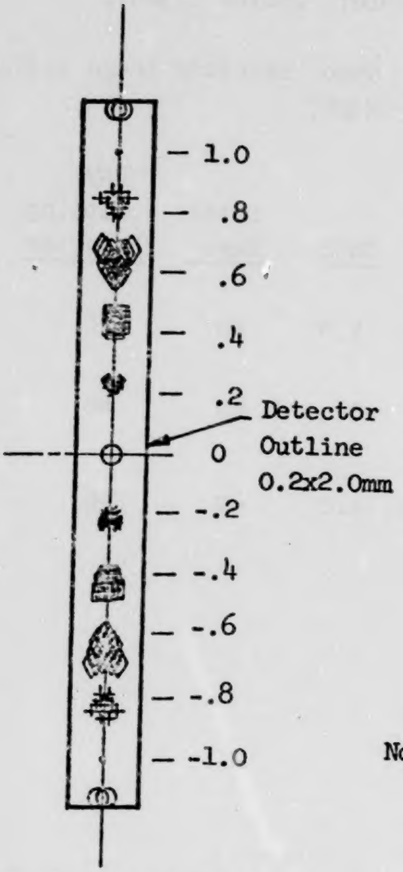
Figure 3.4.5.4 Dall-Kirkham + On-Axis Ellipse

Data 3/8/70

1. Image 9.29 mm high at Telescope Focus

2. Det. Optics 5.326:1

3. Theo. Detector Image 1.74 mm High; Clustered at Heavy Dots



Scale: 1 in = 0.5 mm

	OBJH	Total Rays	Rays Hitting Detector
○	1.0	1	1
+	.8	5	5
◊	.6	10	10
□	.4	13	13
×	.2	22	22
⊕	0	40	40
×	-.2	22	22
□	-.4	13	13
◊	-.6	10	10
+	-.8	5	5
○	-1.0	1	1
		142	142

Effective Transmission = $\frac{142}{142}$ = 1.00

Note: 48 Rays Attempted Each OBJH

Figure 3.4.5.5 Telescope System + On-Axis Ellipse

The "Cassegrain" system was investigated with both the Dall Kirkham telescope and the Telescope System; the results are shown on Figures 3.4.5.6 and 3.4.5.7.

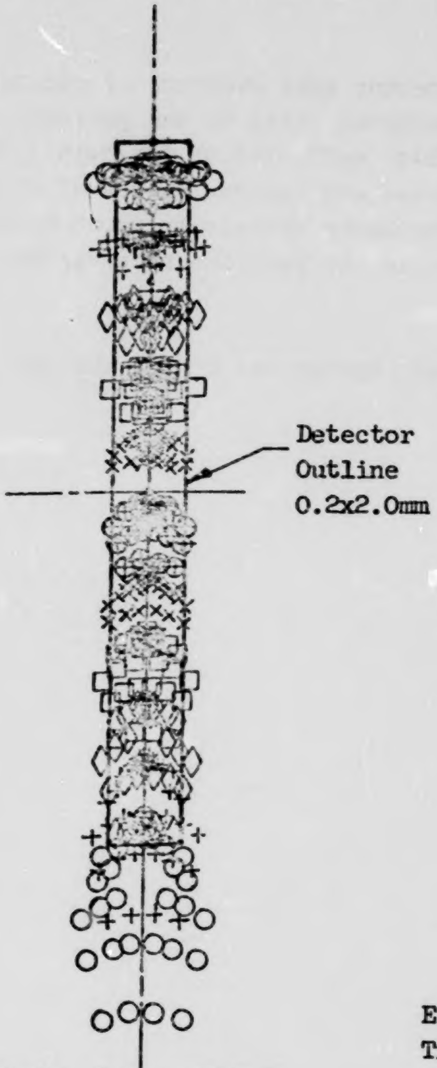
The superior performance of the Cassegrain detector system over the 90° off-axis ellipse is clearly evident.

Figure 3.4.5.8 shows the effect on the detector spot diagrams of adding the monochromator (with a field lens at the entrance slit) to the previous Dall Kirkham + "Cassegrain" configuration. This configuration represents the total system for the emission mode. Only extreme and central values of object height were used to conserve time. The monochromator spreads the spot diagram only slightly, demonstrating that its omission in the previous runs was not significant.

On the basis of these results the Cassegrain system was chosen for the detector optics.

Data 6/14/70

1. First Order Image 12 mm High at Telescope Focus
2. Det. Optics 6:1 Theo.
3. Theo. Detector Image 2 mm High; Clustered at Heavy Dots
4. Crosses are Locations of Chief Ray
5. 40 Rays Each OBJH Reach Det. Plane



Scale: 1 in = 0.5 mm

	OBJH	Rays Hitting Detector
○	1.0	28
+	.8	32
◊	.6	34
□	.4	36
×	.2	38
⊕	0	38
×	-.2	38
□	-.4	36
◊	-.6	36
+	-.8	26
○	-1.0	18
		360

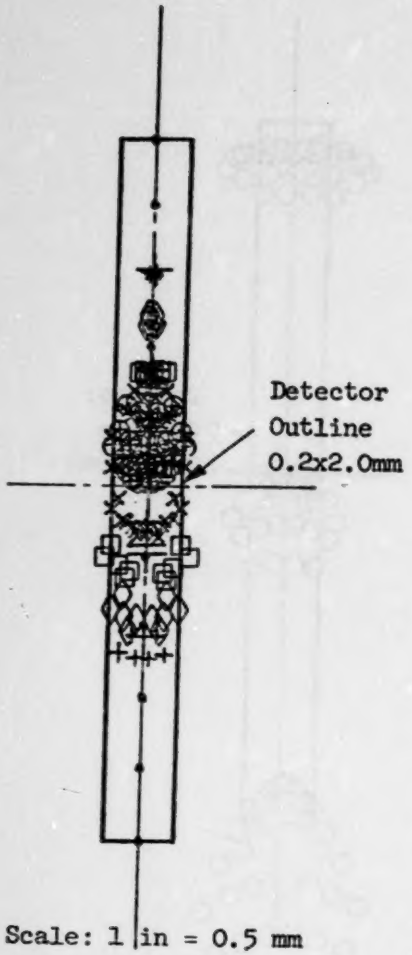
$$\text{Effective Transmission} = \frac{360}{440} = 0.81_8 \sim \underline{0.82}$$

Note: 52 Rays Attempted Each OBJH

$$\frac{360}{572} = 0.62_9$$

Figure 3.4.5.6 Dall Kirkham + Detector "Cassegrain" System

1. Ra = 0.4 Km.
2. First Order Image 9.29 mm High at Telescope Focus
3. Det. Optics Theo. 6:1 Reduction
4. Theo. Detector Image 1.55 mm High; Clustered at Heavy Dots
5. Crosses indicate Position of Chief Ray



	OBJH	Total Rays	Rays Hitting Detector
○	1.0	0	0
+	.8	6	6
◊	.6	10	10
□	.4	10	8
×	.2	22	20
○	0	40	38
×	-.2	22	22
□	-.4	10	10
◊	-.6	10	10
+	-.8	6	6
○	-1.0	0	0
		136	130

Scale: 1 in = 0.5 mm

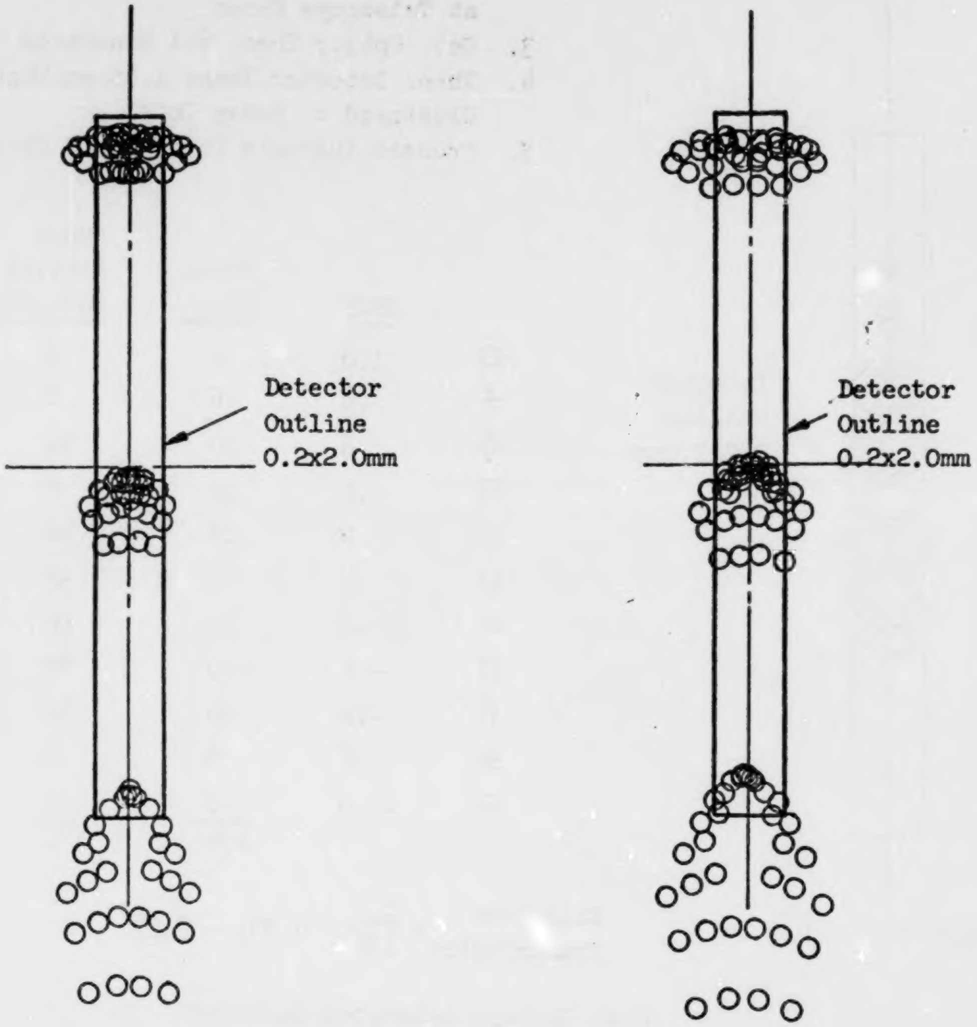
$$\text{Effective Transmission} = \frac{130}{136} = 0.95_5 \sim \underline{0.95}$$

Note: 52 Rays Attempted Each OBJH

Note: Plotted Pattern Inverted
Because Neg. Object
Height Used

$$\frac{130}{572} = 0.22_7$$

Figure 3.4.5.7 Telescope System + Detector "Cassegrain" System



Scale: 1 in = 0.5 mm

Dall Kirkham Tel.
+ Toroid + Det. Cass.
OBJH = 0, ±1.0
Data 6/14/70-4

Dall Kirkham Tel.
+ Monochr. + Toroid + Det. Cass.
OBJH = 0, ±1.0
Data 6/20/70-2
(Incl. Field Lens at Entr Slit)

Figure 3.4.5.8 Effect of Monochromator on Emission Mode Performance

3.4.6 Detector

Both mercury doped germanium (Hg:Ge) and mercury-cadmium-telluride (MCT) detectors were considered for use on this system. Considering performance, methods of cooling and cost it was decided to use the (Hg:Ge) detector.

The size was chosen as 0.2 by 2.0 mm which is the size used by the monochromator manufacturer. Further size reductions would require faster detector optics which would be less efficient than that used in this system.

The field of view of 90° and the location of the aperture mask were chosen to be compatible with the "Cassegrain" detector optical system.

3.4.7 Synch Systems

There are two synch systems (one for the source chopper and one for the reference chopper) required for use by the lock-in amplifiers in order to reduce noise.

The source synch is only used in the transmission mode of operation. Part of the beam from the source telescope is intercepted by the source synch receiver mounted on the side of the receiver telescope. Signals from this detector after filtering and amplification are applied to the reference input of the source channel lock-in amplifier.

Since the signal from the source telescope with the bare detector would be inadequate at long ranges a lens system was incorporated in the synch receiver. An objective lens having a clear aperture of about 45 mm diameter and 147 mm focal length is imaged onto the detector (1.5 mm nominal) by means of a field lens which is a 4 mm focal length, 43 × N.A. = 0.65 microscope objective lens.

At very close ranges such as those used in the laboratory and for ranges below about 200 feet the source telescope beam does not diverge enough to fill the synch receiver objective. Therefore, a periscope device which picks off a portion of the main beam has been provided for use in these situations.

The optical diagram for the synch receiver is shown schematically on Figure 3.4.7.1. Details of the synch receiver shown on drawing 596-722-017.

The reference chopper synch signal is obtained from a photodiode mounted on the reference chopper housing. It is illuminated by a light emitting diode (LED) mounted on the other side of the chopper housing so that the chopper blade passes between the LED and the photo diode. Electrical details are given in Section 3.6.2 and 4.3.2.

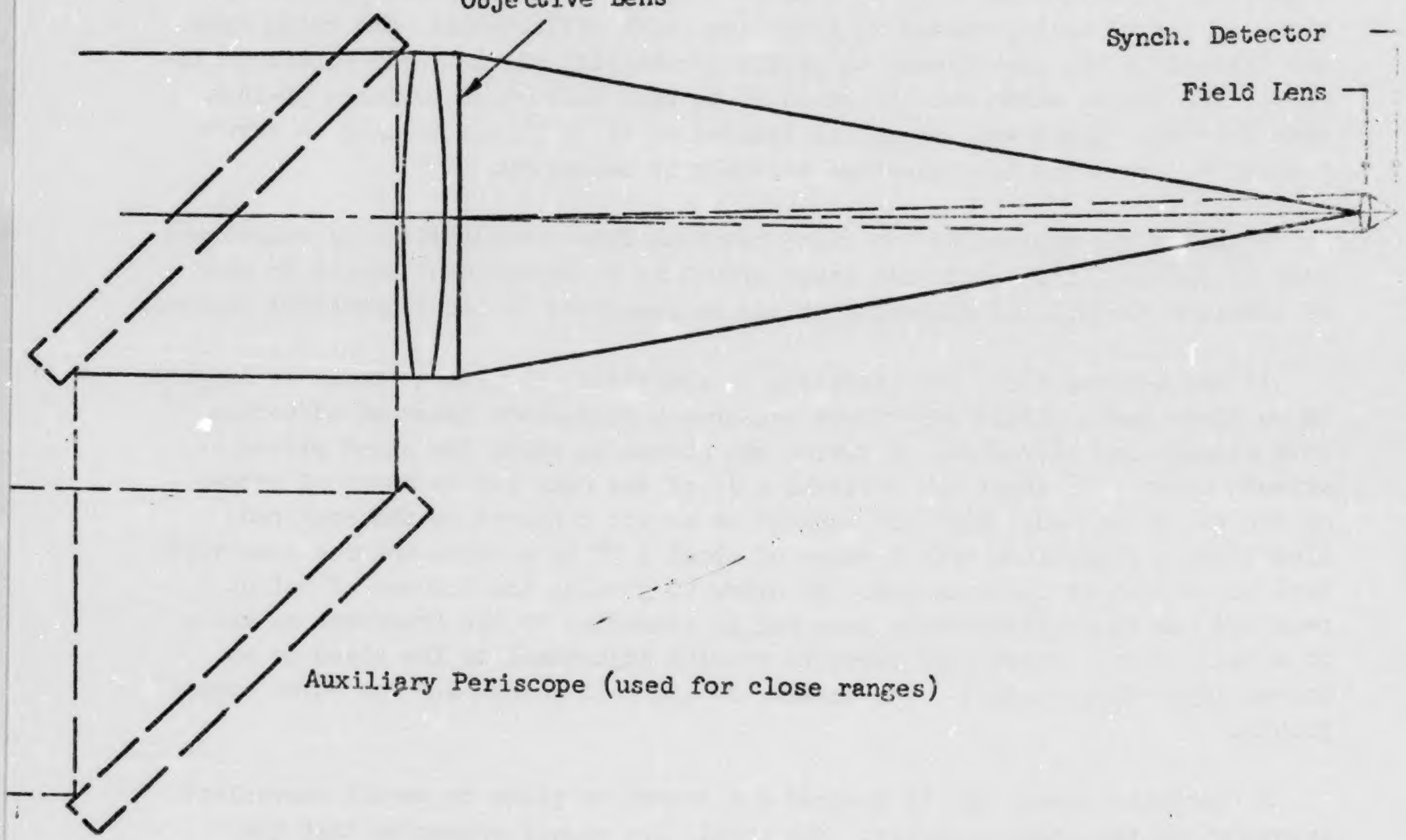


Figure 3.4.7.1 Source Synch Receiver

3.5 MECHANICAL SYSTEM DESIGN

There are a number of mechanical considerations which can best be described in relation to the system. These include the stands, the telescopes and the reference and detector optical system mounts. These are discussed, in turn, in the following sections.

3.5.1 Stands

The stand is the basic framework which supports the various components and holds them in proper alignment. The principal design requirement is to limit the deflections with minimum weight. Preliminary designs using shells and box beams were discarded in favor of a truss framework mainly because the truss geometry can be easily varied to carry the loads efficiently. The stand size was limited by the requirement to permit portability particularly within buildings. The design width was chosen so as to pass through an ordinary 30-inch wide doorway. The stand length was limited so as to permit turning in narrow hallways by removing the telescope assembly if necessary.

Aluminum was chosen for the stand material from consideration of weight and ease of fabrication. Since all other structure of significant length is made of aluminum the optical alignment should be preserved as the temperature changes.

It was decided that, for stability in operation, the stand should be supported on three pads. Field adjustment requires a convenient means of adjusting both azimuth and elevation. A system was chosen in which the stand pivots in azimuth about $\pm 1^{\circ}$ about the vertical axis of the rear pad by means of screws on the two front pads which are tangent to an arc centered on the rear pad. Elevation is controlled over a range of about $\pm 5^{\circ}$ by a screw which allows vertical adjustment of the rear pad. In order to provide the freedom of motion required for these adjustments each pad is connected to the framework by means of a ball joint. These also serve to provide adjustment of the stand to an uneven supporting surface. The centers of the ball joints are the three support points.

Retractable wheels can be lowered and locked in place to permit convenient transport of the stand assembly. The wheels are widely spaced so that the assembly will be stable under any combination of component installation.

The telescope is the largest and heaviest component mounted on the stand. Although it would have been desirable to support the telescope on both ends this would have considerably extended the stand length which would have made manufacturing difficult. Alternatively, a separate support could have been placed at the front of the telescope but this would disturb the alignment since the loads would be redistributed. Consequently, it was decided to support the telescope at its rear face by means of three mounting pads on the stand.

For economy the source and receiver stands are nominally identical. Because of the additional equipment mounted on the receiver stand numerous additions to the basic stand were made. These include provision for mounting: 1) the receiver blackbody; 2) the electrical interface panel connections; 3) the preamplifier; 4) the source synch preamplifier; and 5) the mercury lamp and its power supply.

The source blackbody on the source stand occupies roughly the same position as does the monochromator on the receiver stand, namely at the telescope focus. Each should have a complete range of adjustments and therefore a similar mounting plate is used for each insofar as its attachment to the stand is concerned. These plates may each be raised or lowered by means of three screws. Each plate has adjustments on the top to permit lateral or fore and aft motion of the unit mounted; i.e., the monochromator on the receiver stand and the source blackbody on the source stand. In the latter case, the blackbody is mounted on a plate having the same outline dimensions as the monochromator. Locking devices are provided to hold the adjustments.

The exterior of the stands are covered with removable flat panels which improve the appearance and provide protection to enclosed components. They are readily removable for service.

3.5.2 Telescopes

The principal mechanical design problems related to the telescopes were the method of mounting of the primary and secondary mirrors and the method of mounting the telescope as a whole. The mirror substrate selection problem associated with thermal-mechanical variation of the primary mirror was also considered.

Primary Mirror Mount

Mainly on the basis of thermal considerations aluminum was selected for the telescope mirror substrate material. At first it was thought to be advantageous to support the primary mirror at the center hole. However, bending in the support structure required to transfer the loads out to the telescope mounting pads was excessive considering the small space available for structure.

The suggestion of the telescope manufacturer to support the primary mirror by means of tie rods through radial holes in the mirror was adopted after their assurance that such holes would not cause surface variations. The tie rods are anchored in a sturdy ring which distributes the loads to the telescope mounting pads.

Secondary Mirror Mount

Various methods of supporting the secondary mirror were considered including a truss framework connected to the primary mirror support as well as the more conventional shell and vane construction. The latter was adopted mainly on the basis of stability and ease of fabrication.

Telescope Mount

It was considered necessary to make the telescope removable from the stand in order to pass through narrow hallways. Also, if the telescope ever required repair or resurfacing of the mirrors, it would be desirable to ship only the telescope. It was decided to mount the telescope by means of three pads on the back face in order to ensure stability of the alignment (see Section 3.5.1 also). So long as the telescope is tested and operated with the operational support configuration the alignment should be constant (in the absence of vibration). If vibrations were ever to become a problem a non-contacting dashpot is to be added below the front of the telescope to provide damping (however, no such requirement has arisen in the field tests). Of course, material should not be laid on the telescope nor should personnel lean on it while in operation.

Thermal Considerations

The effects of thermal expansion on the telescope focal position were investigated as were the effects of thermal expansion on the focal length and form of the primary mirror.

An equation for image movement at the telescope focus in terms of constructional variations is given in a chapter on telescopes by K. Bahner*,

$$da = m^2 df_1 + (m-1)^2 df_2 - m^2 de$$

where a = distance from secondary vertex to image

$m = f/f_1$

f = system focal length

f_1 = primary focal length

f_2 = secondary focal length

e = distance from primary to secondary vertices.

It is noted that df must be negative for a negative secondary focal length.

---

* Volume 29 of the Encyclopedia of Physics, Springer-Verlag (1967).

The primary mirror vertex is taken as the reference position. The distance from the primary mirror vertex to the image equals g. From the above relation then,

$$dg = da - de$$

$$dg = m^2 df_1 + (m-1)^2 df_2 - (m^2 + 1)\, de$$

A calculation of thermal effects has been made for the system having an f/2.0 primary mirror and a +30°F temperature change.

System	da	dg
All aluminum	+ .01650	+ .00550
Pyrex mirrors + zero expans. sep.	+ .01395	+ .01395
Pyrex mirror + Invar separator	+ .01270	+ .01250
Pyrex mirror + aluminum separator	- .05480	- .06580
Pyrex mirror + component separator	+ .00666	+ .00550

For an all aluminum system the value of dg = +.00550 is just equal to the expansion of 15 inches of the aluminum structure. Thus, the position of the focus relative to the entrance slit does not change with temperature. Note that the shift of the focus for Pyrex mirrors with respect to the primary vertex, dg, is negative for an aluminum separator and positive for an Invar separator. Also the desired value of dg = +.00550 to match the aluminum structure lies within the range defined by these two values. Therefore, a combination of aluminum and Invar will match the desired value as shown in the last entry (~ 91% Invar; 9% alum.).

On the basis of other thermal considerations (see below) it was decided to use aluminum substrates for the mirrors. Therefore, the simpler all-aluminum structure was chosen.

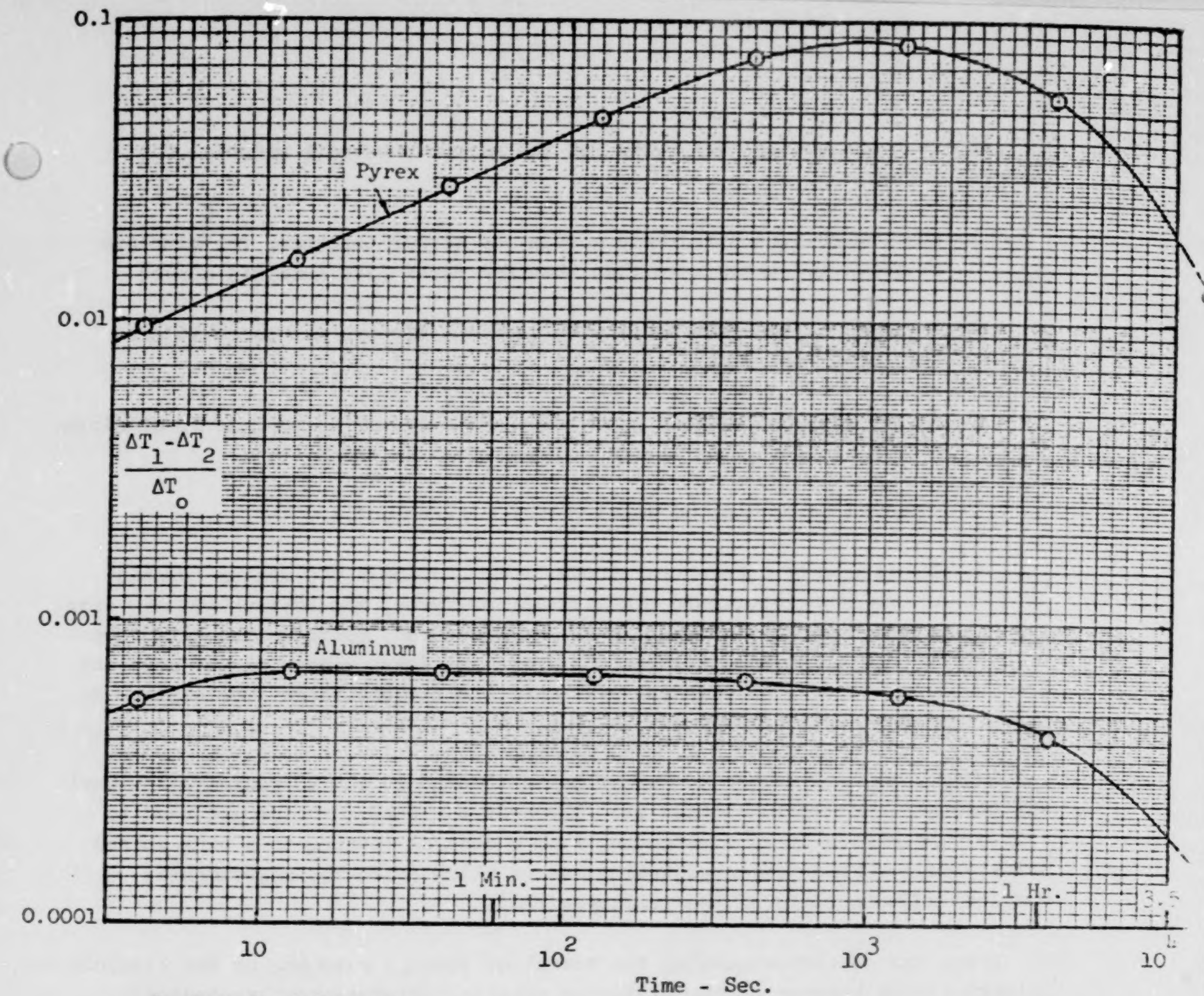
Several analyses have been made to assist in the selection of a substrate material for the mirrors. Of particular interest, here, is an analysis showing the difference in temperature between the front and rear surfaces of the mirror resulting from a different emissivity (i.e., one side polished and the other not).

The mirror was assumed to be a slab (edge heat flow neglected) having different surface conductances at each side. Linear heat flow into an ambient at zero temperature produces temperature gradients. The solution given in H.S. Carslaw and J.C. Jaeger*, page 126, case 3.11 (ix) has been solved and run on the computer. The results are shown in Figure 3.5.2.1. Note that the temperature difference in the case of Pyrex is over 100 times greater than that for aluminum and the peaks difference occurs at a later time (nearly 20 minutes after the temperature change). The maximum temperature difference across the Pyrex slab is about nine percent of the initial temperature difference. Thus, a 30°C mirror placed suddenly in a 20°C environment would have an initial ΔT_o of 10°C and for Pyrex would result in a temperature nearly 20 minutes later at the polished surface about 0.9°C above that at the opposite face. A similar aluminum mirror would experience a temperature difference between the faces of less than 0.01°C.

These results for the Pyrex mirror are used in the following estimate of the effect on the telescope focus position. Assuming the mirror section to be bent in a circular arc, the slope change at the edge would be $\alpha r\ (\Delta T_1 - \Delta T_2)/(L = 5\ \text{cm}) \sim (3 \times 10^{-6})(30\ \text{cm})(0.9^\circ\text{C})/5 \sim 16 \times 10^{-6}$ radian. A tangent to the mirror face would thus move about $30 \times 16 \times 10^{-6} \sim 480 \times 10^{-6}$cm at the axis which corresponds to a change in sagitta of about 240×10^{-6}cm or 2.4 microns or about 5 wavelengths of visible light. This is nearly twice the tolerance of ± 3 wavelengths given for fabrication. This change in slope would produce a displacement of the normal of about 0.0016 inches at the center of curvature and the normal would cross the axis about 0.0016 (96/12) ~ 0.013 inches farther from the mirror for an equivalent increase of focal length of about 0.007 inches. The final telescope focus would shift away from the mirror about $m^2 df_1 = 6.25\ (0.007) \sim 0.044$ inches. In contrast, the aluminum mirror focal shift would be negligible.

---

*H.S. Carslaw and J.C. Jaeger, Heat Conduction in Solids, Oxford (1959).



Surface Heat Transfer
$\times 10^4$ (cal/sec cm^2 K)

Conv.	$H_{c1} = .89$	$H_{c2} = .89$
Rad.	$H_{r1} = .075$	$H_{r2} = 1.39$
Total	0.965	2.28

ΔT_o = Initial Temp. Diff. (from ambient)

ΔT = Temp. Diff. (from ambient) → 0 as time → ∞

Properties

	Alum.	Pyrex	
K	0.48	0.0026	cal/sec cm K
ρ	2.70	2.23	gm/cm^3
c	0.206	0.117	cal/gm K
k	0.86	0.007	cm^2/sec

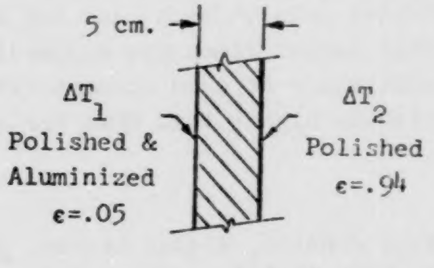


Figure 3.5.2.1 Temperature Differences in a Slab

Aluminum was chosen over Pyrex for the mirror substrate material for several reasons:

1. The temperature difference across the mirror thickness for aluminum is about 100 times less than that for Pyrex (see analysis above).
2. The cost of the telescopes with aluminum mirrors was somewhat less than that for Pyrex.
3. Use of aluminum mirrors allows the whole system to be made of aluminum, thus simplifying the thermal compensation of the system.
4. Improved technology of metal mirror production*.
5. Experience of others* particularly H.L. Johnson who states "Because of the low temperature conductivity of Pyrex, the 28-inch primary warps appreciably with changes in air temperature. On the other hand, the 60-inch (aluminum) telescope's image and focus remain almost constant with temperature changes, even over the extreme range from daytime to nighttime temperatures."

The primary mirror has 20 radial holes through it and 20 radial holes part way through in order to lighten it. Three of the through holes are used to support the mirror on rods extending from a central fitting to a ring-shaped primary cell. Three axial adjusting screws allow (with rod adjustments) complete adjustability of the primary mirror.

There was concern regarding the transient thermal response of the aluminum primary mirror because of the differing material thicknesses. Accordingly, analyses have been made to determine the maximum transient difference in temperature in the mirror when subjected to a step change in environmental temperature.

In the first analysis radial heat flow was neglected. Typical sections were chosen at various radial positions (see Figure 3.5.2.2). Each section was divided into elements and the maximum temperature difference in each section (unit radial dimension assumed) was determined from a computer run giving the temperature of each element versus time. As expected, these differences were slightly higher than that for a comparable solid slab.

*H.L. Johnson, Vistas Astron. 10, 155 (1968) quoted by F.L. Forbes, Appl. Opt. 7, 1361 (1969) and F.L. Forbes, Appl. Opt. 7, 1407 (1969).

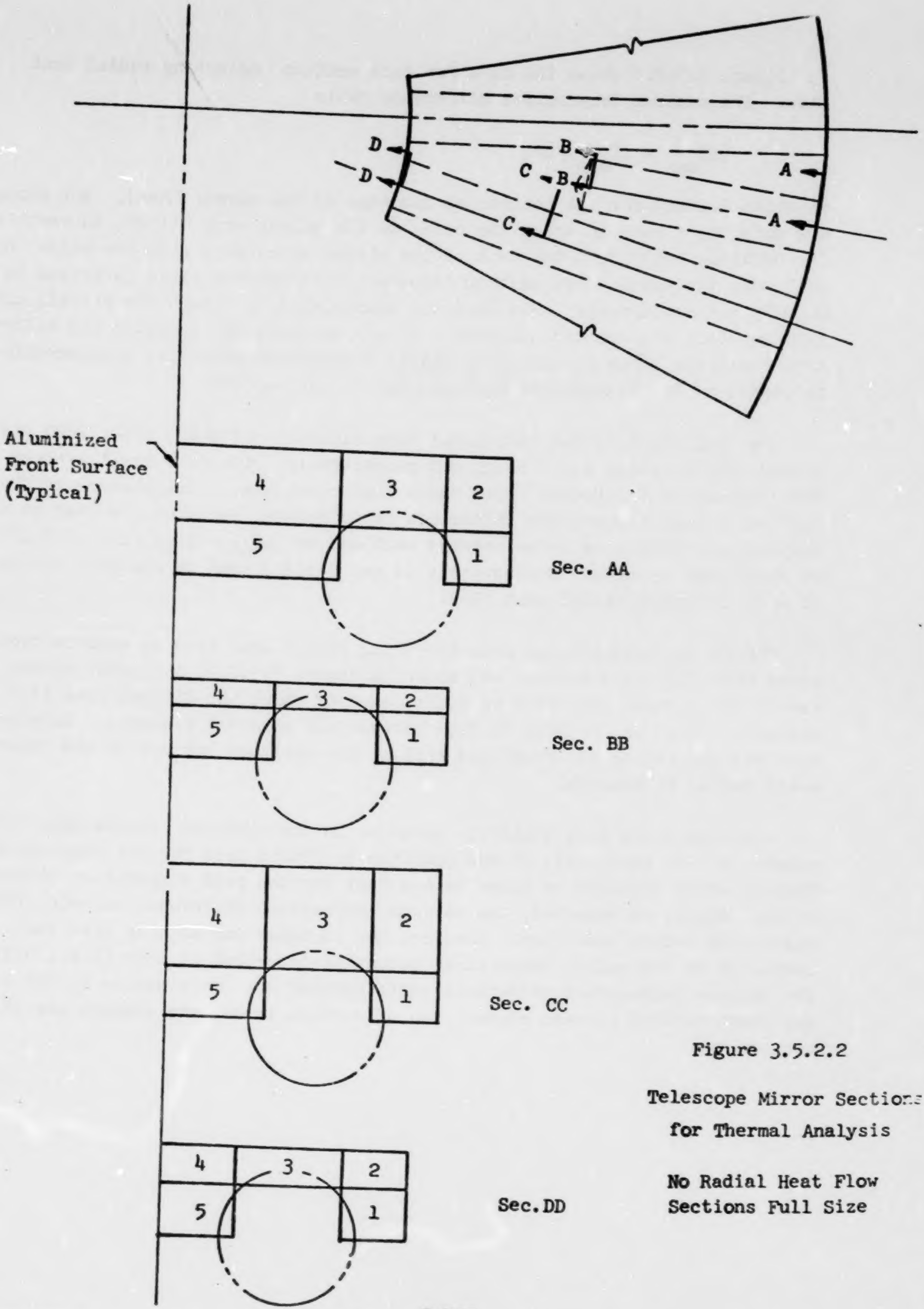


Figure 3.5.2.2

Telescope Mirror Sections for Thermal Analysis

No Radial Heat Flow
Sections Full Size

Figure 3.5.2.3 shows the data for each section neglecting radial heat flow. The maximum temperature difference ratio

$$(\Delta T_{max} - \Delta T_{min})/\Delta T_o$$

is about 0.00214 for the section at the edge of the mirror (A-A). Not shown are data for a case in which the holes in the mirror were allowed to ventilate (by drilling holes from the back of the mirror to connect with the radial holes). With hole ventilation the maximum temperature difference ratio increased to 0.00247 and consequently this idea was abandoned even though the overall mirror time constant was reduced slightly. It was observed the sections had different time constants which results in a radial temperature potential considerably in excess of the temperature differential in any section.

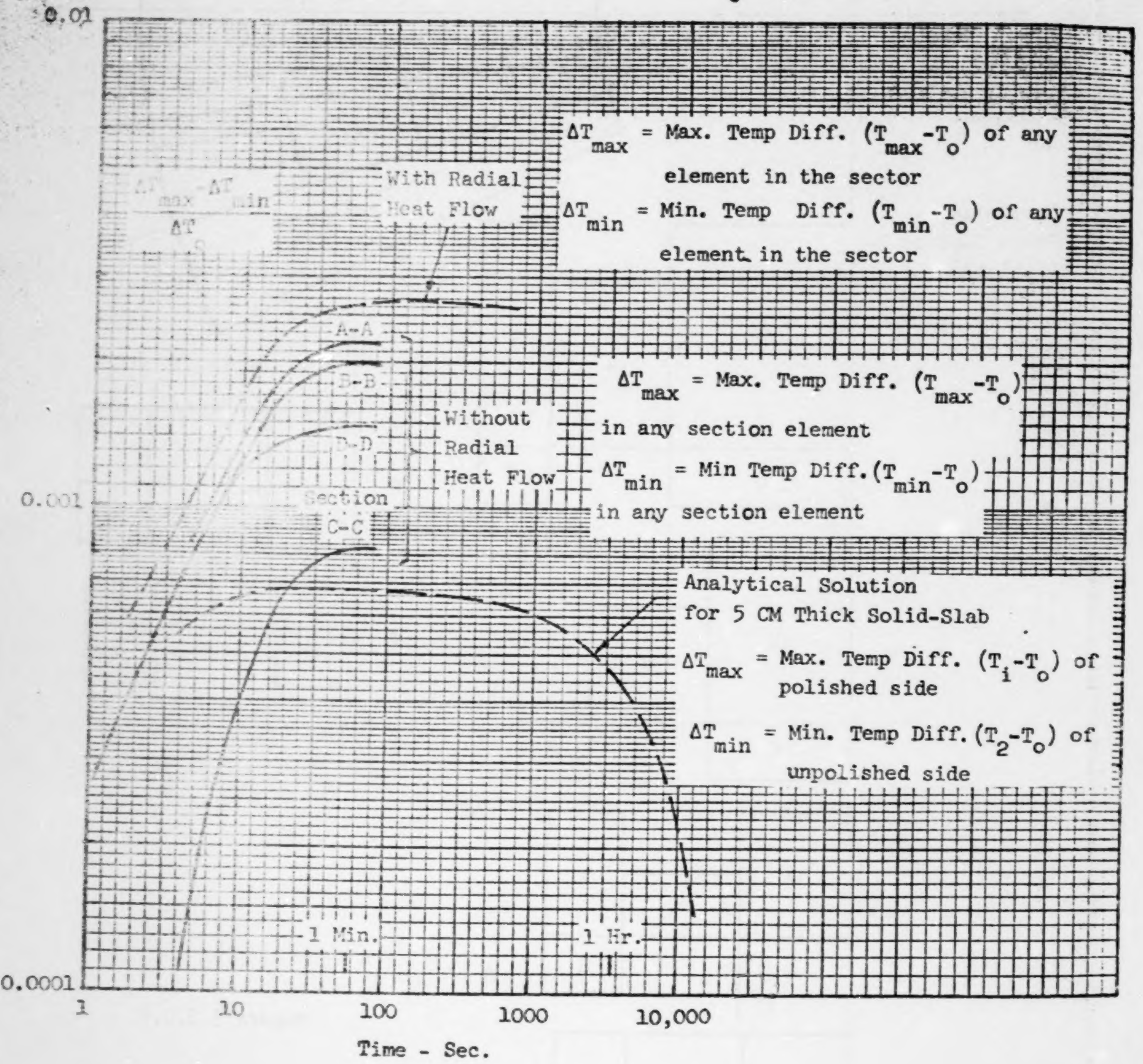
The four sections had individual time constants of 9460, 6750, 7620 and 5910 seconds for sections A-A through D-D respectively, with an overall average of 7200 seconds or two hours. With these time constants, extrapolation to the time of maximum temperature difference ratio between sections resulted in a temperature difference ratio between sections of $(\Delta T_{AA} - \Delta T_{DD})/\Delta T_o$ of 0.172 at about 7200 seconds. Consequently it was decided that an analysis should be made including radial heat flow.

The second analysis was made including radial heat flow as well as transverse heat flow used before. As shown in Figure 3.5.2.4, a typical mirror sector was divided into five sections, each of which was divided into five elements. Heat was allowed to flow between all adjacent elements. External flux was applied to the front and back mirror surfaces but not to the inner and outer radial boundaries.

Although there were stability problems in the computer calculations (not uncommon in such analyses), it was possible to obtain data for the temperature history which extended to times beyond that for the peak temperature difference ratio. Again, as expected, the maximum temperature difference exceeded that neglecting radial heat flow. However, the increase was nothing like that indicated by the radial temperature potential described earlier (i.e., 0.172). The maximum temperature difference ratio between any two elements in the sector was about 0.00266 between element two of section three, and element six of section two.

ΔT_o = Initial Step Temp Diff.
= $T_{Mirror} - T_o$

Material: Aluminum
T_o = Ambient Temp



ΔT_{max} = Max. Temp Diff. $(T_{max} - T_o)$ of any element in the sector
ΔT_{min} = Min. Temp Diff. $(T_{min} - T_o)$ of any element in the sector

ΔT_{max} = Max. Temp Diff. $(T_{max} - T_o)$ in any section element
ΔT_{min} = Min Temp Diff. $(T_{min} - T_o)$ in any section element

Analytical Solution for 5 CM Thick Solid-Slab
ΔT_{max} = Max. Temp Diff. $(T_i - T_o)$ of polished side
ΔT_{min} = Min. Temp Diff. $(T_2 - T_o)$ of unpolished side

Figure 3.5.2.3 Transient Temperature Differences in a Telescope Mirror

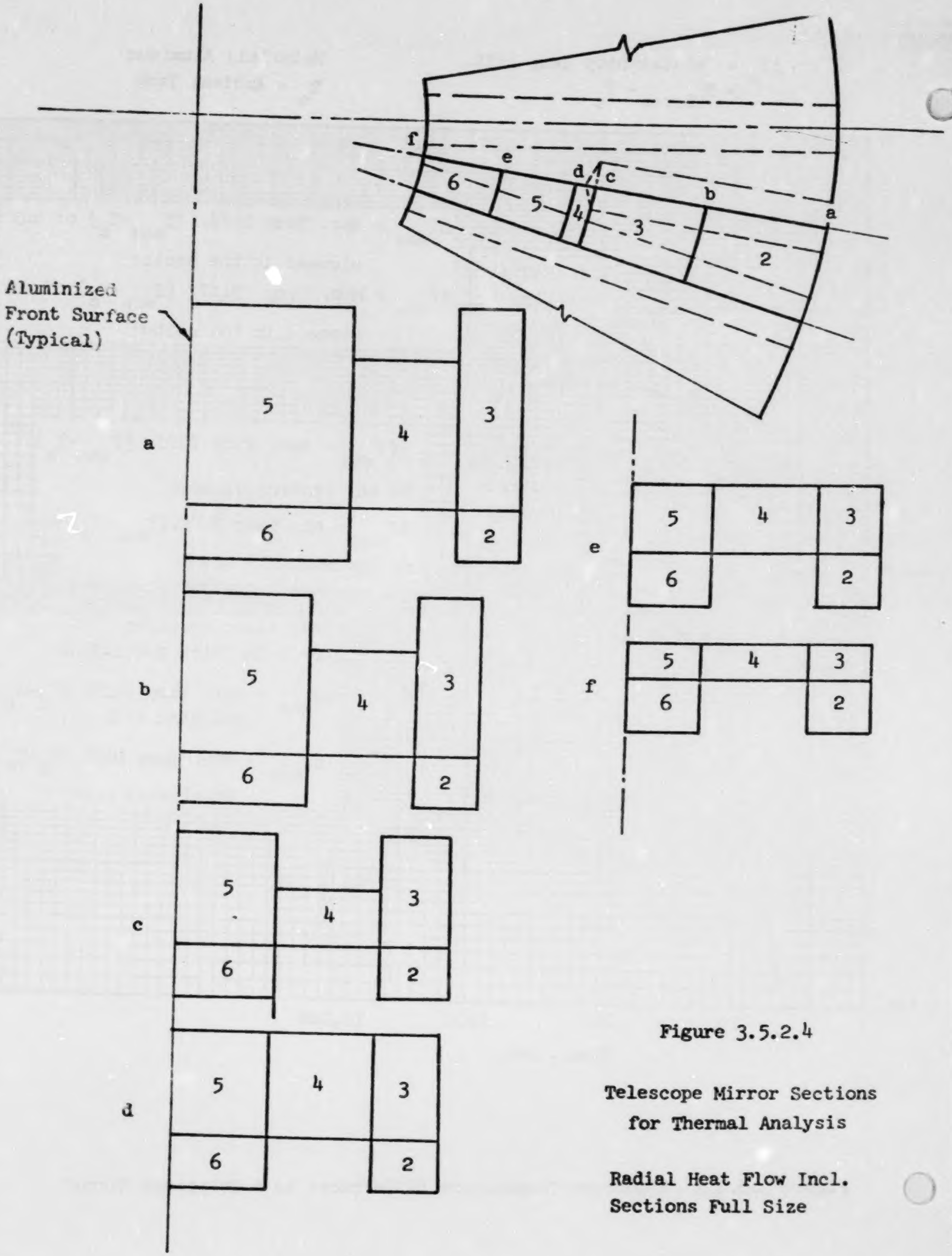


Figure 3.5.2.4

Telescope Mirror Sections for Thermal Analysis

Radial Heat Flow Incl. Sections Full Size

The determination of the effect of the calculated temperature distribution on the focal spot condition is very difficult. However, a crude estimate may be made by comparison with the calculation made previously for the Pyrex mirror, in which a focal shift of 0.044 inches was calculated for a mirror temperature difference of 0.9°C. With the assumed step change of 10°C in ambient temperature

$(\Delta T_{max} - \Delta T_{min})/\Delta T_o = 0.9/10.0 = 0.09$. The present value of

$(\Delta T_{max} - \Delta T_{min})/\Delta T_o$ of 0.00266 for the aluminum mirror is about thirty times less.

Assuming the focal spot degradation to be roughly proportional to the temperature difference, the degradation with the aluminum mirror should be negligible, perhaps barely discernible by the most sensitive test. The effect is probably less than estimated above, since changes in temperature of 10°C are not likely in a few minutes.

It is important to distinguish between deformations of mirror form and deformations of mirror size. Temperature differences in the mirror may cause changes, mainly in the form of the mirror, which result in shifts in the position of the focus as well as variations in image intensity distribution. The previously described analyses show that such variations should be small for the telescope as designed. Temperature changes of the primary mirror as a whole from the initial temperature cause its size (and therefore focal length) to change. The position of the focus depends on this change as well as changes in the mirror separation, secondary mirror size and support structure size (see equations given for image movement).

Assume the telescope is in focus prior to $t = 0$, and all temperatures are equal. Assume a step change in ambient temperature at $t = 0$. All of the elements of the system will change toward the new ambient temperature, each with its own time constant and eventually (after several hours) all the temperatures will again be equal to the new ambient temperature. If all parts of the system are made of the same material the whole system will have grown proportionally and the position of the focus relative to the entrance slit will be equal to that prior to $t = 0$.

In the meantime, however, the relative positions will be determined by the various time constants of the critical system elements. One can judge the change in the position of the focus relative to the entrance slit by comparison of the value of dg calculated by the equation below with the value of dg calculated for the support structure expansion or contraction.

$dg = m^2 df_1 + (m-1)^2 df_2 - (m^2 + 1)\, ds$

g = distance from primary vertex to focus

$m = f/f_1$ (= 2.5 in this case)

f = system focal length (= 120 in. = 304.8 cm)

f_1 = primary focal length (= 48 in. = 121.92 cm)

f_2 = secondary focal length (= -30 in. = -76.2 cm)

s = distance between primary and secondary vertices (= 30 in. = 76.2 cm).

In general, any length element is a function of temperature:

$$\ell = \ell_i + \alpha\, \ell_i \Delta T_e$$

where ℓ_1 = initial value of ℓ

$\Delta T_e = T - T_i = (T-T_o) - (T_i-T_o) = \Delta T - \Delta T_i$

T_i = initial temperature

T_o = ambient temperature

α = coefficient of thermal expansion = $26 \times 10^{-6}/^{o}C$ for aluminum

For $t \geq 0$, all values of $\Delta T_i = 1.0$ and the values of ΔT are shown in Figure 3.5.2.5 as a function of time. The time constant of each element is calculated from:

$$\tau = c\rho V/HA$$

where c = specific heat (= 0.206 cal/gm for aluminum).

ρ = density (= 2.7 gm/cm^3 for aluminum).

H = heat transfer coefficient

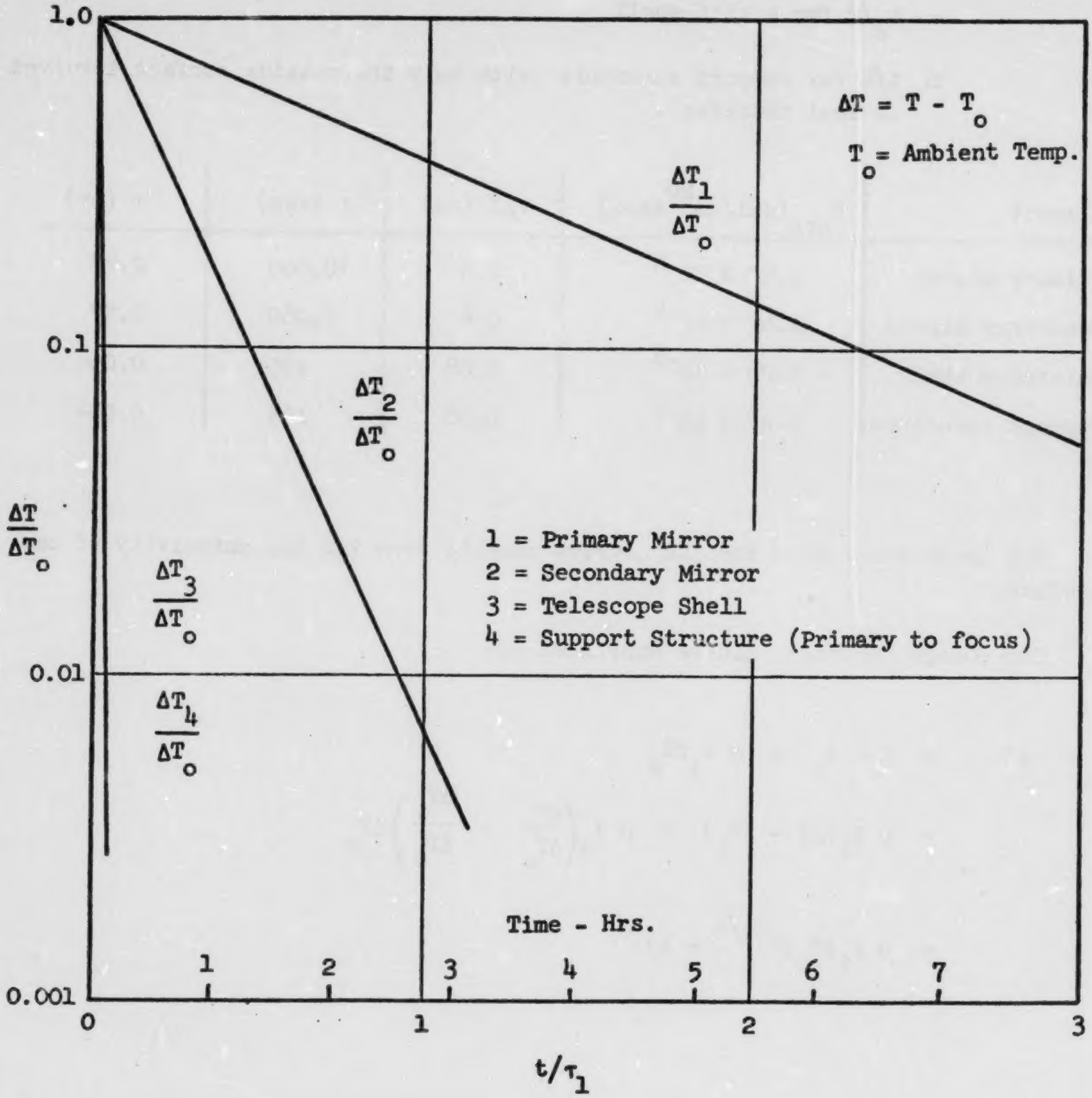


Figure 3.5.2.5 Temperature vs. Time of Telescope Elements

V/A = geometrical factor

= $t_{avg}/2$ for a thin disk

= $t_s/2$ for a thin shell

≅ t/4 for support structure (with only the outside surface involved in heat transfer).

Element	H_{avg} (cal/cm^2 °K sec)	V/A (cm)	τ (sec)	τ (hr)
Primary mirror	1.62×10^{-4}	2.9	10,000	2.78
Secondary mirror	1.62×10^{-4}	0.6	2,060	0.57
Telescope shell	2.28×10^{-4}	0.08	195	0.054
Support structure	2.28×10^{-4}	0.08	195	0.054

The lower value of H for the mirrors results from the low emissivity of one surface.

The change in length can be expressed as:

$$\Delta \ell = \ell - \ell_i = \alpha\, \ell_i \Delta T_e$$

$$= \alpha\, \ell_i (\Delta T - \Delta T_i) = \alpha\, \ell_i \left(\frac{\Delta T}{\Delta T_o} - \frac{\Delta T_i}{\Delta T_o} \right) \Delta T_o$$

$$= \alpha\, \ell_i \Delta T_o (e^{-t/\tau} - 1)$$

Using these data the change in the focus is:

$$dg = (6.25)\left[\alpha f_1 \Delta T_o \left(e^{-t/\tau_1} - 1\right)\right] + (2.25)\left[\alpha f_2 \Delta T_o \left(e^{-t/\tau_2} - 1\right)\right]$$

$$- (7.25)\left[\alpha s \Delta T_o \left(e^{-t/\tau_3} - 1\right)\right]$$

$$= \alpha \Delta T_o \left[6.25\, f_1 \left(e^{-t/\tau_1} - 1\right) + 2.25\, f_2 \left(e^{-t/\tau_2} - 1\right) - 7.25 s \left(e^{-t/\tau_3} - 1\right)\right]$$

The change of the entrance slit position (relative to the primary mirror) will be governed by the expansion of the support structure:

$$dg' = \alpha \Delta T_o g \left(e^{-t/\tau_4} - 1\right)$$

The relative position of the focus and entrance slit is determined by dg - dg′ which is shown on Figure 3.5.2.6 for a change of ambient temperature $\Delta T_o = 1^oC$. The peak shift of the focus relative to the entrance slit occurs about 14 minutes after the temperature change. If the change occurred at the beginning of a 14 minute run, the effect of the change, if significant, would be detected in calibrations before and after the run. Changes in the system after about 15 minutes take place quite slowly, and would therefore have less effect (about twenty times less) on calibration change during a run.

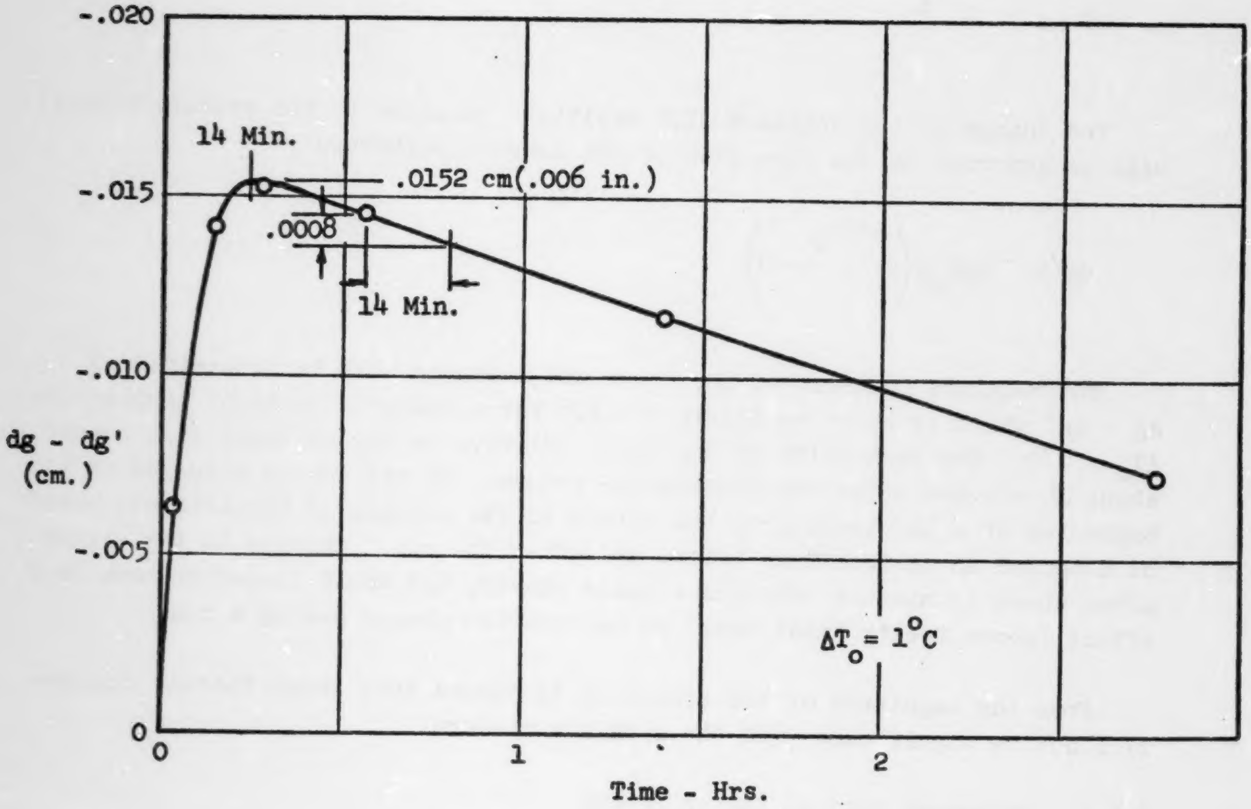
From the magnitude of the effect it is judged that these thermal changes will not be significant with the aluminum mirrors.

3.5.3 Reference Optical System Mounts

There are two features of the reference system mounts which are related to system requirements.

Provision is made in the mounting of the spherical mirror for its removal to permit insertion of the radiation probe into the reference blackbody in order to check its radiance whenever desired. The mount for the spherical mirror is strictly kinematic to assure precise positioning.

Provision is also made at the intermediate focus for inserting a blocking plate to block the reference beam during initial set-up. It is also possible to mount a mercury lamp at the intermediate focus for alignment and/or calibration purposes.



dg = Focus Pos. Change

dg' = Ent. Slit Pos. Change

Figure 3.5.2.6 Difference in Position of Focus & Entrance Slit

3.5.4 Detector Optical System Mount

The mounting of the detector "Cassegrain" involved consideration of not only alignment of it and the detector but the installation of the detector as well. The detector is mounted on a slender cold finger within a dewar to protect it from the atmosphere. The dewar is attached to the refrigerator cold head. There are two flexible hoses connected between the cold head and the compressor (in the auxiliary stand). These lines may exert a considerable force on the dewar and its mounting; therefore, the dewar mounting must be quite rigid. Although it would be desirable to have fine adjustments on the location of the detector (and therefore the dewar) it is difficult to construct these adjustments with sufficient rigidity. Consequently it was decided to provide only lateral adjustment of the detector-dewar assembly and to provide for the more precise focus adjustments in the mounting of the "Cassegrain" assembly.

3.5.5 Detector Cooler

The major mechanical problem associated with the detector cooler is vibration.

The most suitable closed-cycle coolers, in terms of performance and price, are produced by Malaker and by Cryogenics Technology (formerly 500 Inc.), a subsidiary of A. D. Little. Representatives of both companies brought in samples of their coolers for demonstration. The Malaker unit was available for a week to allow evaluation.

In addition to the demonstrations and tests, the choice of coolers was discussed with several users of these devices in other aerospace companies and in government laboratories and with detector manufacturers who integrate the detector with the cooler. These evaluations indicate that there is a vibration problem associated with the Malaker cooler.

A number of tests were made with the water-cooled Malaker unit to determine the approximate amplitude of vibration with a calibrated microscope. With the cooler mounted on blocks as recommended by the manufacturer, the peak-to-peak deflection was about 30 microns, regardless of the mass attached to the system. The cooler was attached to a model 210 monochromator by means of a $3 \times 3 \times \frac{3}{8}$ inch aluminum angle with the cooler hanging vertically downward over the edge of the bench. Observations on a plexiglas window showed a deflection again of about 30 microns peak-to-peak. Various attempts to reduce the vibration by clamping the monochromator to the bench with large C-clamps and/or restraining the body of the cooler produced only a small reduction, if any, in amplitude. Finally, the monochromator was clamped to a large, heavy (approximately 2000 lb) surface plate; the window and the cold head vibrations were slightly less than 30 microns and in different planes, The cooler was removed from the monochromator and weighted down and clamped in blocks onto the surface plate. The deflection of the cooler was more than 100 microns; the surface plate vibration was roughly 30 microns peak-to-peak. A check was made to ensure that the observed motion was not that of the microscope by observing another tripod with the cooler operating; no motion was observable. From these tests it was concluded that the vibration would not substantially be reduced by addition of mass to the cooler. In a subsequent discussion Malaker representatives agreed with this conclusion.

Consideration was next given to means of isolating the cooler vibration from the detector and the pedestal structure. This requires mounting the cooler on vibration isolation mounts (a separate support was judged operationally unacceptable) and providing low transmission couplings for the vacuum jacket and the detector heat flow path. Various opinions were obtained from persons familiar with vibration problems from which it was concluded that an appreciable technical risk would be involved in the isolation approach.

As a result, the alternative higher priced ADL cooler was considered more closely. The model 0125 is a relatively new 60 cycle version of a 400 cycle model 0120 cooler, which was demonstrated.

In the demonstrations it was observed that the vibration of the model 0120 refrigerator was markedly less than that of the Malaker unit. These observations and experience of others indicate that the vibration levels of the ADL cooler are an order of magnitude less than those of the Malaker cooler and are acceptable for the present application.

The Cryogenics Technology representatives indicated that vibration of the model 0125 refrigerator would not be greater than that of the model 0120.

Later, a vibration test of the CTI cooler, Model 0125, was made at Convair under operating conditions.

With the refrigerator head C-clamped to the edge of a bench, a vertical motion of the relection of a laser beam from a mirror mounted on the refrigerator of about 1/32 inch pp was observed at a distance of about 20 feet (beam deflection ~ 1.1 mrad or mirror deflection ~ 0.6 mrad peak-to-peak). A screwdriver placed between the refrigerator and the bench reduced this deflection so as to be undetectable. The refrigerator case was observed with a microscope to move about 3 to 5μ, with or without the screwdriver brace (operating temperature ~ 15°K).

The cooler was next C-clamped to a light stand (1 x 1 x $\frac{1}{8}$ angle 24 x 34 inches on four legs $\frac{7}{8}$ O.D. x 0.09 wall pipe ~ 26 inches long, with no bracing). Again, a motion of three to five microns was observed. Restraining the compressor hose, about four feet from stand, increased the vibration about 50 percent.

The refrigerator was then C-clamped to a stand 34 x 60 x 36 inches tall, made mainly from 3 x 3 x $\frac{1}{4}$ inch aluminum well braced. The motion of the refrigerator case was less than 3µ, peak-to-peak.

The cold tip was next observed using a glass pipe dewar and a plexiglas end plate. No vibration was observed with the vacuum pump operating. Initially, at room temperature, with compressor outlet/inlet pressures of 390/50 psig, a deflection of about 40µ ± 10µ of the cold tip was observed along the motor axis. If the compressor was turned off and the Δp reduced (~ 110/110 psig), the vibration reduced below the limit of detectability (~ 6µ). With a hydrogen sensor pressure of about 7 psig (~ 18°K) at the cold tip and compressor pressures of 260/100 psig, a deflection of about 20µ ± 7 µ of the cold tip (along the motor axis) was observed. Manufacturer specifications state that the refrigerator motor speed is 200 rpm (equivalent to 200/60 ~ 3.3 cycles/sec). This was roughly the observed frequency.

The vibration which we observed does not appear on the vibration spectrum of a similar prototype Model 0120 cold tip. The manufacturers representative stated that vibration spectrum supplied by CTI was run without the compressor attached; thus accounting for the absence of the observed operational vibration. CTI personnel are currently considering a re-design of the cold-finger to reduce the vibration level.

Results of vibration tests made at CTI were received by telephone from CTI which explain the above observed cold head vibration data. Initial tests at CTI confirmed our results. It was found that the mounting flange was attached to the refrigerator via an O-ring (not in a groove), thus allowing freedom not present in normal installation. Further test at CTI after correct installation gave the following peak-to-peak vibration results for the cold finger:

Operation	Δx	Δy	Δz
Refrigerator only Operating	3µ	1µ	0.1µ
Compressor and Refrigerator Operating	5µ	3µ	5µ

Δx is along the refrigerator motor axis (others not defined)

These results were obtained by eliminating the O-ring and operating the system without a dewar and, therefore, the cold head was not at operational temperature. However, there is little doubt that similar results would be obtained at operating temperature.

The above data are judged to be satisfactory and the CTI model 0125 cooler was selected for use in the ROSE system.

3.5.6 Detector

The mechanical configuration of the detector is shown in the specification drawing Figure 4.1.6.1. The detector mounting details are shown in the Component Details Section 4.2.9.

3.5.7 Synch Systems

The major mechanical system requirement for the synch systems is for a sturdy mounting of the sensitive elements. Details of these mounting arrangements are given in Component details Section 4.2.11.

3.6 ELECTRONIC SYSTEM DESIGN

3.6.1 The Electronic System

The electronics system is defined to be all aspects of instrument components that perform an electronic function, as well as the electronics associated with components that serve a mechanical or optical function. An example of components that are mechanical in nature are the choppers. The chopper motor drive circuitry and electrical characteristics of the motors is covered in the electronic system description. However, the function, mounting, physical characteristics, etc., of the choppers will be found under the mechanical description. An electronic component such as the signal preamplifier would be described as to function, electrically, and mechanically in the electronic system.

The system design section is limited in scope to an operational description of the electronics. It is intended to give the reader a systems understanding and operational capability. Circuit descriptions, schematics, troubleshooting procedures, physical dimensions, etc., are covered in the electronics system details portion of this document.

The system has been divided into seven subsystems and both the system design discussion and system details section are divided into these seven subsystems: Signal Sources, Signal Amplifiers, Wavenumber Generation, Data Aquisition, Data Recording, Electronic Calibration, and Power Subsystems.

3.6.2 Signal Sources

There are five (5) signals associated with the instrument; source (I), Reference (I_o), source synch, reference synch, and wavenumber. These are grouped below according to the source from which they are derived.

Source and Reference - Hg:Ge

The source (I) and reference (I_o) signals are both generated by the cooled Hg:Ge detector. The output of the mercury doped germanium (Hg:Ge) detector in the transmission mode of operation of the instrument is a combination of (I) and (I_o) signals. The magnitude of the (I) portion of the signal is determined by the intensity of the chopped remote blackbody and the atmospheric path. The frequency of the (I) signal is determined by the variable speed source chopper. The magnitude of the reference portion of the signal is determined by the intensity of the reference blackbody and its frequency by the fixed frequency reference chopper. When the instrument is operating in the emission

mode, there is no reference (I_0) signal, or blackbody sources. The source of signal now becomes the atmospheric or pollutant emission. Output of the Hg:Ge detector in this mode has an amplitude proportional to the emission and a frequency equal to the reference chopper frequency. The low level nature of these signals requires narrow bandwidth amplification and detection to produce an adequate signal to noise ratio. This requirement generates the need for the source and reference synch signals.

Source Synch

This signal is used as a frequency and phase reference for the source lock-in amplifier. The source synch signal is produced by intercepting a portion of the signal beam and focusing it on an Indium Arsenide (InAs) detector. This signal will have the same frequency as the source (I) signal and will have a fixed phase relationship to it. It is used only when the instrument is operating in the transmission mode.

Reference Synch

The reference synch signal is produced by a light emitting diode (LED) and diode detector. The reference chopper intercepts the light beam producing a synch signal of equal frequency and fixed phase relationship to the reference signal. This signal is used for the reference lock-in amplifier synch in both the transmission mode and the emission modes of operation.

Wavenumber Generation

Additionally, a signal must be provided to indicate the wavenumber corresponding to the instantaneous grating position. This signal is generated by an incremental digital shaft encoder that is mechanically ganged to the grating drive mechanism. The particular encoder used generates nine thousand logic level pulses per shaft revolution. These pulses are fed into pulse counting logic circuitry that produces output pulses equal to the number of 0.1 wavenumbers per shaft revolution for the respective grating.

3.6.3 Signal Amplifiers

The source, reference, and the associated respective synch signals are generated as low level signals and must be amplified.

Source and Reference Amplification

The source (I_o) signal must be linearily amplified and rectified in a narrow band amplifier. The mixed signal (I) and (I_o) output of the cooled detector is first preamplified. The preamplifier is a Princeton Applied Research (P.A.R.) variable gain general purpose broadband preamplifier. The output of the preamp is coupled through the standard signal-operate switch to two selective amplifiers. The selective amplifiers are P.A.R. narrowband amplifiers that provide for center frequency adjust, gain selection and variable "Q". These amplifiers each selectively pass the preamplified signal components at the source chopper frequency or reference chopper frequency. The output of the selective amplifiers serves as the input to the lock-in amplifiers. The lock-in amplifiers are modified P.A.R. Model 220 amplifiers. The amplifiers provide for center frequency adjust, sensitivity, time constant selection, and phase adjust. The center frequency adjust tunes the lock-in amplifier to the synch signal frequency; the time constant control determines the instrument bandwidth; the sensitivity selection controls the gain of the lock-in amplifier. The phase control adjusts the phase of the respective synch signal to coincide with the phase of the signal. The resultant effect these amplifiers have on the signals is to convert them to narrow bandwidth d.c. voltages. The modifications made to the P.A.R. 220 lock-in amplifiers have altered some parameters displayed on the front panel. The panel has been changed to conform to the new values of time constant and sensitivity. The output impedance of the lock-in amplifiers is 5K ohms. The next operation to be performed on the signal requires a low source impedance. This necessitates the insertion of unity gain amplifiers. The unity gain amplifiers are integrated circuit amplifiers that share a circuit board with the compensation amplifiers. They are a Convair design and are located in the logic chassis. They provide the low driving impedance the compensation amplifiers require for accurate gain determination. The compensation amplifiers are used to compensate for the effects on the signals due to the sharing of a common chopper. Since both the source signal and reference signal are chopped by the reference chopper the source signal is reduced (nominally one-half) compared to the reference signal. The source compensation amplifier restores the source signal to its proper level and provides the adjustment necessary to calibrate the electronic gain. Calibration is accomplished by adjusting the input of the source compensation amplifier with a potentiometer mounted on the control panel. Proper source channel gain is provided by a gain equal to eight. Under the condition where the atmospheric absorption is equal to zero, a combination of the potentiometer set at $\frac{1}{4}$ of maximum, a gain equal to eight would yield the proper source signal level assuming no vignetting.

The reference compensation amplifier is a differential amplifier with unity gain. The output of the reference channel voltage follower drives the inverting input while the source channel voltage follower drives the non-inverting input. The reference compensation amplifier output is set to zero with the reference beam blocked in an initial set-up procedure. This makes the reference compensation amplifier output independent of source signal variations. With the block removed from the reference beam the output of the reference compensation amplifier depends only on the reference beam. See the radiometry Section 3.3 for a more detailed description. Further processing of the signals is accomplished in the data acquisition system.

Synch Signal Amplification

There are two synch signals; the source synch and reference synch. These signals are required by the respective lock-in amplifiers as their reference input. The reference synch amplifier is the simpler of the two. The method used to generate this signal provides a relatively high-level signal. Consequently, the reference synch detector can drive an integrated circuit operational amplifier directly. In this case it is an amplifier with a gain of one thousand that is driven into saturation by the synch signal. The bandwidth of the amplifier is constrained from 200 Hz to 1300 Hz for the purpose of avoiding the amplification of the noise that appears across the high impedance input. The narrow band feature of this amplifier is, however, of no consequence as the reference chopper that generates the signal is fixed in frequency at approximately 330 Hz. Source synch signal amplification is much more difficult because in a long path length condition the detected signal may be as low as 0.7 microvolts. Additionally, the variable nature of the source chopper requires that the amplifier have a wider bandwidth. To satisfy these requirements, it was necessary to first transformer couple the signal into a preamplifier. The transformer provides voltage gain and matches the low impedance detector to the high input impedance of the preamplifier. The preamplifier is a three-stage, discrete component, JFET amplifier with a gain of 500. Due to the fact that the power supply voltage used to power the L.E.D. contains 120 Hz ripple, this frequency presented a special difficulty. The insertion of an integrated circuit amplifier connected as a 120 Hz gyrator in the signal line at this point provided sufficient 120 Hz rejection. A line driven amplifier follows the gyrator; it amplifies the signal to a level such that the signal may be transmitted by coaxial cable from the receiver stand to the electronics console. Inside the electronics console the signal is further amplified into saturation. This is done in two stages: The first stage is a low pass amplifier with gain equal to ten thousand (10K) and the second stage is a high pass amplifier with gain equal to one thousand (1K). The net result is an amplifier that saturates at the lowest level of detected synch signal with a bandwidth from 340 Hz to 720 Hz. The two synch signals now are identical except in frequency. They are square waves with ±15V swing which will provide a phase reference to the lock-in amplifiers and drive the standard signal generators.

3.6.4 Wavenumber Generation

In the discussion of signal sources it was mentioned that the wavenumber was generated by a shaft encoder mechanically ganged to the grating drive mechanism. The number of pulses the encoder generates is nine thousand (9K) per shaft revolution. However, the information required is the actual wavenumber to a resolution of 0.1 wavenumbers. This is accomplished by feeding the 9K counts per revolution into logic circuitry that converts them to the number of 0.1 wavenumbers per shaft revolution. These output counts from the logic are added to the count or actual wavenumber displayed on a counter. The logic scheme is somewhat complicated by the fact that there are two gratings and the number of wavenumbers per shaft revolution is not only different for each grating but may also be a function of the alignment of the monochromater and the environment. This complication is handled by making the output of the logic circuitry selectable from the control console. Hence, depending on the grating in use and the wavelength calibration, the proper number of 0.1 wavenumbers per revolution may be selected from the control console. The logic circuitry is divided into a number of sections depending on the function served. Each will be functionally discussed here and detailed further in the electronic system details section.

Pulse Shaping Logic

The pulse shaping logic has as its input the clockwise (CW) and counter-clockwise (CCW) pulses generated by the shaft encoder. The logic first examines the pulses and makes two decisions. First is the pulse a noise spike or real pulse? Second is it the second consecutive and non-coincident pulse indicating motion in one direction? If these conditions are met, it then enables a gate that drives the coarse range counter and a monostable multivibrator. The monostable multivibrator delays this pulse and then drives the fine range counters. The reasoning behind these operations is based on the fact that vibration of the encoder may cause it to generate noise pulses. This circuitry takes advantage of the fact that these noise pulses are often coincident or alternating on the CW and CCW lines and differ in duration from real pulses. Hence the result is a successful separation of noise and actual rotational pulses. The fine range counters inputs are delayed so no coarse counter output and fine counter output will be coincident and therefore lost to the output.

Direction Sensing Logic

The direction sensing logic senses CW or CCW rotation of the encoder which corresponds to increasing or decreasing wavenumber respectively. This logic function then serves two purposes. First, it steers the output of the logic to the (X) or (Y) input of the bidirectional counter where the (X) and (Y) inputs are the up and down counting inputs of the counter respectively.

The other use of the direction sensor is to enable the data resolution counter. To avoid possible backlash problems, data is acquired only when the instrument is scanning up in wavenumber. Hence, only CW (i.e., increasing wavenumber) counts are enabled into the resolution counter which generates acquisition of data commands.

Counting Logic

The purpose of the counting logic is to take the incoming 9K pulses per revolution and divide by a number such that the output equals the number of $0.1\ cm^{-1}$ per revolution. This is accomplished by the use of three (3) counters, summing gates, count selector switches and counter reset gates. The three counters are called the ones, tens and coarse counters. Each counter operates independently. The coarse counter is driven directly by the pulse shaping circuit, while the fine counters are driven by these same pulses delayed 4 microseconds. The ones counting logic outputs from 1 to 9 counts per revolution in unit steps. The tens counting logic outputs 10 to 30 or 80 to 160 counts per revolution in steps of ten. The coarse counting logic outputs 500 or 529 counts when the instrument is operative in the 7 to 13.5 micron region and 1125 or 1286 counts per revolution in the 3 to 5.5 micron region. The ones, tens and coarse selector switches on the control panel select the number of counts which appear at the output of its respective counting logic. The summing gates are NAND gates driven by the proper 2^N outputs of the counters so that there is a gate whose output is one of each of the required outputs from each counter. The output of each summing gate is tied to a pole of a multiposition switch. The wiper of this switch goes to an inverting gate and to the counter output logic. The inverting gate is in turn reinverted and connected to the reset lines of its counter. The purpose of this double inversion tied back to the reset is simply to delay the counter reset so that the output at the switch wiper will have sufficient pulse width to enable gates in the counter output logic. In summary the counting logic has as its output three lines: ones, tens and coarse counts. The arithmetic sum of these would be the actual number of $0.1 cm^{-1}$ per revolution if the selector switches were set properly.

Counter Output Logic

The counter output logic input is the output of the counting logic that appears at the selector switch wipers. A two-level or gate sums the pulses for the total count per revolution. The total count goes to either the (X) or (Y) input of the bi-directional counter as directed by the direction sensing logic. The total (X) count also serves as the input to the resolution selector logic.

Resolution Selector Logic

The resolution selector logic consists of a bindary counter, summing gates, a selector switch, and a line driver. The purpose of the resolution selector is to allow for the option of the spectral resolution element at which the data will be outputed. The selector switch allows for resolution elements of 0.1, 0.2, 0.3, 0.5, 1 and 2 cm^{-1}. When a resolution of 0.1 cm^{-1} is desired all of the counting logic (X) output pulses are inverted and connected to a position on the resolution selector switch. When resolution less than 0.1 cm^{-1} is required a counter gate and summing gates divide the 0.1 cm^{-1} pulses by the proper factor and the summing gate outputs are wired to the various selector switch positions. The output of the resolution selector switch (wiper) is inverted and then drives an additional inverter and a monostable. The double inverted pulse is used to reset the resolution counter with the small inherent delay.

Data Control Logic

The monostable is used to provide sufficient pulse width to drive the data control output. The data control output is the signal that commands the data acquisition system to take a reading. It must drive two instruments, the data coupler and the sample-hold digital volt meter (D.V.M.). The input pulse width requirements of these instruments dictated the use of a monostable. Additionally the drive requirement of the coupler requires that the monostable output drive a Darlington emitter follower as its input impedence is approximately 50 ohms on the read input line. The combination of the monostable and Darlington amplifier are jointly referred to as the data control logic.

3.6.5 Data Acquisition Subsystem

The purpose of the data acquisition subsystem is to convert and format the outputs of the instrument into signals acceptable to the data recording subsystem. This means that the counts representing wavenumber must be counted and converted to Binary Coded Decimal (BCD). The ratio of the output of the source compensation amplifier to that of the reference compensation amplifier must be calculated to yield transmission (τ); both analog and BCD representations of (τ) are required. Additionally the source compensation amplifier output must be sampled coincident with particular wavenumbers and converted to BCD. There are four (4) signal converters in the data acquisition subsystem. They are: a presetable bi-directional counter, a ratio D.V.M., a sample-hold D.V.M., and an analog ratio module. These converted signals must then be put into the proper format and timed to the recording units. For the digital data these functions are performed by the data coupler.

Wavenumber Conversion

This conversion is made by the bi-directional counter an Anadex Model CB-600R with preset zero, preset count level, BCD output and "Readout on the Fly" options. The counter has two inputs (X) and (Y) and is operated in the (X)-(Y) mode. The (X) or C.W. output of the wavenumber generator logic goes to the (X) input of the counter and (Y) or C.C.W. logic output to the (Y) input. The resultant count due to grating motion is the net equivalent number of 0.1 cm^{-1}. If the preset zero switches are used to set the initial value of wavenumber the result is the actual wavenumber. The normal method of operation is to set the monochromator to a known wavenumber, set the preset zero switches to the number and press reset. Then during the scan the counter reading will increase in value to the end of the scan. The monochromator is then hand cranked back and the counter will track down. The BCD option converts the count appearing in the windows into BCD logic level voltages at the rear output connector. The BCD output is required as an input to the printer and digital tape recorder. The "Readout on the Fly" option allows the counter to internally track the count without changing the reading in the windows or output. This is necessary because the time required to record and/or print may exceed the time required to scan to the next 0.1 wavenumber. "Readout on the Fly" effectively holds the counter reading while data is being recorded and then updates the counter output to the actual value when the data recording cycle is completed.

Source Digital Output Conversion

The output of the source compensation amplifier will usually change rapidly with wavenumber. Consequently the time at which a reading is made of the value should coincide precisely with the indicated wavenumber. This dictates the use of a sample and hold technique on the reading. A Dana Model 5403-015 digital voltmeter is used in this system to provide both the voltage resolution and high speed sample and hold required. The pulse on the data control line from the logic box that commands data output to the printer or recorder also enables a read to this D.V.M. Hence, the D.V.M. reading and wavenumber indicated on the counter correspond. The data coupler in turn inhibits a change in counter or D.V.M. reading until all the data has been outputed to the printer and/or recorder. The D.V.M. converts the D.C. voltage at the output of the source compensation amplifier to BCD with ten (10) volts being full scale and with four (4) digits of resolution plus over-range of 10%.

Transmission Coefficient (τ) Digital Output Conversion

A Dana Model 5403-010 is used to convert the outputs of the source and reference compensation amplifiers into the BCD value of transmission. This is done by using the voltmeter in its ten (10) times ratio mode with the voltmeter reference being the reference compensation amplifier output and the input being the source compensation amplifier output. The result is a voltage which is 10 volts full scale resolved to four digits plus over-range that equals ten times the transmission,(τ). The BCD conversion for this instrument requires approximately 2ms during which time the input may change. The source input can change much more rapidly than the reference input. This fact suggests the operation of the instrument in a mode that would provide a higher accuracy than the normal mode. The source signal is applied to the 5403-015 D.V.M. in the normal manner but the reference signal is applied to the 5403-010 DVM input, the latter being put in the FAST DC mode. The system would then have one D.V.M. measure the source and the other measure the reference. Since the slower D.V.M. would be measuring the slowly changing reference the results would be more accurate. The ratio of the source to the reference signal would be calculated externally to the sytem (in a computer, for example).

Another feature of this D.V.M. that is useful in the system is that in the READ mode it need not be commanded to read. Therefore, for set up, calibration and trouble shooting it may be used as a voltmeter. In the system it is in the HOLD mode and is commanded to read and the reading is held by the data coupler. When not in the hold mode this D.V.M. continues to read at 4 readings per second.

Analog Ratio Module

The analog ratio module is a unit designed by General Dynamics/Convair to provide transmission coefficient, (τ), in analog form for display on the strip chart recorder. The circuit is designed around an integrated circuit multiplier-divider, and its recommended circuit. The resultant ratio is accurate to about ± 2% for a large reference signal. While, not as accurate as the digital ratio, it is more than adequate for the analog display which is not intended to be used for analytical work. The inputs to the ratio module are the same compensation amplifier outputs that serve as inputs to the ratio D.V.M., therefore the analog and digital ratio are equal at all times within the accuracy of the instruments. The output of the analog ratio module is connected to a switch called "strip chart input selector" located on the monochromator control panel. This switch allows for selection of source, reference or ratio input to the strip chart recorder.

Digital Data Coupler

The digital data conversion instruments have an output of thirteen BCD characters. The counter has five characters representing wavenumber, while each D.V.M. has four characters one character set for (τ) and one for source (I). The data coupler on command causes these 13 characters to be recorded on the digital tape recorder and/or the digital printer. The data record sequence is started by a data control output pulse from the logic box which is coupled through the control panel to the data coupler. The data coupler in turn commands the D.V.M.'s to take a reading and holds the counter reading. The read and BCD encode process takes the D.V.M.'s approximately 2 ms. At this time they generate a print command to the coupler, which senses if it should print, record, or print and record. In the PRINT ONLY mode it commands the printer to print. The printer then starts printing and simultaneously holds off the data coupler. All thirteen BCD characters are simultaneously printed in parallel across one printer line. This process takes approximately 52 ms after which the printer releases the coupler which in turn enables another data control pulse and the counter. The D.V.M.'s will however hold their previous value until commanded by the next data control pulse to read. The RECORD ONLY mode is selected by the switch on the coupler front panel and allows the coupler to command magnetic tape recording. This mode requires a different scanning and output format. Only one BCD character can be recorded on tape per byte. The coupler must then command and increment the tape deck thirteen (13) times for each data word. Again the data control pulse initiates the data record sequence. The coupler generates read commands to the D.V.M's and holds the counter. A print return command upon completion of digitization by the D.V.M.'s activates a clock in the data coupler. The clock pulses sequentially cause a record and increment of the digital tape recorder. After completion of the recording of the thirteen bytes the coupler again enables a data control pulse and the bi-directional counter. The RECORD ONLY data output sequence takes 26 ms and is therefore approximately twice as fast as the print only mode. The RECORD ONLY mode has one distinctive feature not incorporated into the PRINT or PRINT AND RECORD modes. Should a data control pulse occur during the RECORD ONLY mode it is ignored; if a data control pulse occurs during the other data recording modes the coupler hold may, on occasion, cause a system halt.

The system halt is removed by pressing the reset button on the coupler front panel. Data recording then restarts with the intervening data missing. The RECORD ONLY mode ignores this halt so that maximum possible data may be obtained at the fastest recording speed even if requested resolution elements must be ignored.

The PRINT AND RECORD mode is a combination of the two separate modes. When the coupler function switch is set to PRINT AND RECORD a data control pulse initiates the print sequence and record cycle. The counter and data control enable are inhibited until completion of the record cycle. The time required by this sequence is the larger time interval of the individual operations (i.e.-52ms). Data recording can be manually commanded by pressing the "start" button on the coupler which then makes a single data record cycle. The "Write Error" indicator lamp on the coupler indicates a parity error and can be removed by the reset command. The "Tape Not Reading" lamp indicates the tape is not properly loaded.

3.6.6 Data Recording Subsystem

As was previously indicated there are three (3) data recorders. The strip chart is an H.P. Model 7701A with a Model 8801A low gain D.C. preamplifier. It serves as the only analog recording device. Digital data recording is done on an H.P. Model 5050B line printer and on a Kennedy Model 1600H incremental digital tape recorder. Each of these recorders were incorporated to give the instrument a particular capability. These capabilities and the various recorder limitations are described below while detailed specifications are covered in the specifications section, the electronic details section and in the respective recorder manuals.

Strip Chart Recorder

The strip chart recorder provides a visual real-time display of system operation. It is a very useful tool in system set-up and evaluation procedures. The recorder will display the source (I), reference (I_o) or (τ) as selected by the recorder input switch located on the monochromator control panel. This display can be used during instrument set-up to find and identify known structure in the atmosphere. Prior to an actual data scan a rapid scan displayed on the strip chart can be used to adjust the gain of the system for maximum output without exceeding full scale. The strip chart display is also the ideal instrument on which to display system drift and noise. With the monochromator fixed in wavenumber the output is displayed on the strip chart giving a record of long term stability and noise. There are a number of limitations associated with the strip chart. All of these limitations concern the difficulties associated with obtaining analytical data from this instrument. No wavenumber information is printed on the strip chart, so wavenumber must be recorded by means of an event marker at the side of the chart and interpolated as required. Alternately, specific structure may be recognized and a linear interpolation used to determine the wavenumber at a point on the graph. Both of these procedures are slow, tedious and the accuracy is less than desirable. The wavenumber accuracy obtained by the interpolation is dependent on the chart drive speed and drive linearity. The amplitude of the signal as read off the strip chart will also have associated errors. These errors consist of chart readability limitations, recorder linearity, recorder frequency response and generally the ratio module accuracy. Chart readability is $\pm \frac{1}{4}$ division in 50 or $\pm \frac{1}{2}\%$. Chart linearity at the extremes is also $\pm \frac{1}{2}\%$. The frequency response of the recorder is down - no more than 3 db at 30 Hz. This implies but does not specify a flat response to the 30 Hz corner frequency. Assuming a flat response to 30 Hz allows this factor to be discounted until the scan speed exceeds 3 resolution elements per second. This is approximately equivalent to scanning a spectral region in four (4 minutes. The ratio module accuracy is ± 1% above 10% of full scale (less accurate below 10% of full scale). The total strip chart amplitude accuracy is therefore ± 1% for source or reference inputs and ± 2% for (τ) input under ideal conditions. Ideal conditions are near mid-scale display and instrument in a slow scan mode.

Digital Printer

The digital printer serves as a visual real-time display of the digital output. It prints thirteen characters in parallel at a maximum rate of twenty lines per second. The thirteen characters are divided into two groups of four, and one group of five decimal characters. Each character represents a window in a D.V.M. or the counter. The left most group of characters are the sample and hold D.V.M. (I) the middle group the ratio D.V.M. (τ), and the righthand group of five the counter (0.1 cm^{-1}). This is illustrated in the table below:

I	$\tau = I/I_o$	0.1cm^{-1}
8221	8227	07476
8222	8228	07475
8222	8228	07474
8254	8241	07473
8221	8227	07473
8221	8228	07471
8221	8228	07469
8222	8228	07467
8221	8228	07465
8222	8229	07463

The printer reproduces the windows exactly so the only errors are the instrument error and data conversion error. The limitation of this display unit are the record form and speed capability. The record produced by the printer may contain a maximum length of 6900 lines when the instrument is operated in the 7-13.5 micron region at 0.1cm^{-1} resolution. The speed capability is 20 lines per second but at this speed some skipping may occur. At the fastest scan speed with high resolution data control (0.1 cm^{-1}) the speed is limited to about 10 lines per second. This means that at 0.1cm^{-1} resolution element scan of the 7-13.5μ region requires a minimum of 12 minutes. Use of the printer in the system reduces the maximum scan rate and if this rate is exceeded the system will skip. If higher data rates are desired without skipping the digital output must be recorded on the digital tape recorder only.

Digital Recorder

The digital tape recorder is a Kennedy Model 1600H. It uses a 7 track tape with byte density equal to 556 BPI and write speed of 0-500 characters per second. The thirteen data characters are recorded sequentially thus requiring thirteen write cycles to record one data set. The data is formatted on the tape in a modified BCD code. The advantages of the digital tape as an output device are its speed and computer compatibility. The cycle time for the digital recording is 25 ms or forty data sets per second. This is about four times as fast as the other output devices. The digital tape recorder will accept 0.1cm^{-1} resolution elements in the 7-13.5 micron region with scan time as low as 2½ minutes. The computer compatibility of this output enables a procedure to generate the other two output formats. Plotting and tabulating routines have been applied to the digital data as recorded on tape to generate analog plots and data tabulations of superior quality. The digital tape output is also the simplest method to input to the computer for computational work. The disadvantages of the digital tape are; no real-time confirmation of data quality, and the modified data format requires an intermediate reformatting procedure. The digital tape recorder has no playback capability and therefore it cannot be demonstrated that the system is operating properly in the field. Some reassurance of proper operation is given by the write error and tape not ready indicators on the data coupler. The seven track tape has tracks designated 1, 2, 4, 8, A, B, C, and a convention has been established for the recording of BCD information on this type of tape. The conventional code format allows for the recording of numerics 0 through 9, all the alpha numerics and some other symbols. For the ROSE system only the numerics zero (0) through nine (9) have significance, and only the 1, 2, 4, 8 tracks are required. Tracks A and B are used as flags while C is the parity bit in this system. A logic "1" in the A and B tracks is used to signify a new data set. A logic "1" in the B track is used to signify the first digit of a new instrument. Hence, every thirteenth byte has A and B equal to "1". B is "1" on bytes 1, 5, and 9, as illustrated below assuming the following readings:

Sample-Hold DVM	Ratio DVM	Counter
00.123	04.567	89876

REPRESENTED DIGIT		1	2	4	8	A	B	C	VALUE OF DIGIT
S-H DVM	10^0	0	1	0	1	1	1	0	0
" "	10^{-1}	1	0	0	0	0	0	1	1
" "	10^{-2}	0	1	0	0	0	0	1	2
" "	10^{-3}	1	1	0	0	0	0	0	3
Ratio DVM	10^0	0	0	1	0	0	1	0	4
" "	10^{-1}	1	0	1	0	0	0	0	5
" "	10^{-2}	0	1	1	0	0	0	0	6
" "	10^{-3}	1	1	1	0	0	0	1	7
Counter	10^4	0	0	0	1	0	1	0	8
" "	10^3	1	0	0	1	0	0	0	9
" "	10^2	0	0	0	1	0	0	1	8
" "	10^1	1	1	1	0	0	0	1	7
" "	10^0	0	1	1	0	0	0	0	6
S-H DVM	10^0	1	0	1	0	1	1	0	5

These flags are used by the computer to count the total number of data sets in a block of data. This is necessary because the total number of bytes in a block may exceed the computer input capacity. The flag bits are counted and if they exceed the computer input capacity the tape is copied with the insertion of end of record EOR gaps. Gaps are not inserted during a data run because the time required to gap would cause the recorder to exclude up to 20 data sets. This deviation from standard format requires a computer input routine so that the insertion of the "1's" in A and B are not interpreted as alpha numberic information. This can be done on the computer or the tape may be copied and restored to a standard format in the support data station.

3.6.7 Electronics Calibration

Electronics calibration consists of an amplitude check of the amplifiers and data acquisition subsystem. The placement of the operate-standard signal switch in the STD SIGNAL position inserts a signal of known amplitude into the instrument just after the preamplifier. The standard signal (τ) potentiometer on the control panel enables this signal to have any ratio of (I) to (I_o) desired by changing the value of the standard source signal. The standard signal may then be sequentially monitored in each amplifier chain and the anticipated values of (I), (I_o), and (τ) checked on the data recorders.

Standard Signal Generation

The standard signal is produced by a circuit called the calibration signal generator which is located in the logic box. The circuit consists of two amplifiers, one for the source and one for the reference standard signal. Each is driven into saturation by its respective synch signal amplifier. These saturated outputs are clipped by zener diodes producing a known amplitude signal at each of the two chopper frequencies. The source calibration signal generator output is connected to the standard signal (τ) adjust potentiometer on the control panel. This potentiometer allows the source standard signal to be any value from 0 to 100% of the reference standard signal. (τ) is therefore whatever value of full scale the (τ) adjust potentiometer selects. The value of the zener clipped signal is 6.2 volts, while a low level signal is needed, to simulate the preamplifier output. Therefore, the two clipped signals are divided down to ±6.2 mv or 12.4 mv(pp) and combined in the standard signal mixer. This resistive divider-mixer provides as its output a signal representative of that present at the output of the preamplifier in the operate mode. When the standard signal-operate switch is in the STD. SIGNAL position the calibration signal is inserted into the amplifier chains.

3.6.8 Power Subsystem

The only input power required by the ROSE instrument is 115 volt 60 Hz. Internal to the instrument power is required in three indirect forms; chopper drive, blackbody heater and D.C. voltages. The conversion of the 115 volt 60 Hz input power to the power requirements of the instrument is explained under these three headings.

D.C. Voltages

The required D.C. voltages are +24, ±15, ±6, and +5 volts. The +24 volts D.C. is provided by the PAR. NIM BIN Model 200. Its primary purpose is to serve as the power supply for the PAR amplifiers. The excess current capability of this power supply is utilized by other circuits; Hg:Ge detector bias current, marker selector and source synch preamp. supply voltages are provided by the +24 volts D.C. supply. A Data Technology Model 597 modular power supply provides the ± 15 volts and + 5 volts. ± 15 volts D.C. are required by the various linear integrated circuits utilized in the signal and synch amplifiers. The total required ± 15 volt power is about 25% of the rated 100 ma of the 597 modular supply. Digital logic circuitry requires +5 volts D.C. and the 597 +5 volt output fills this requirement. Total current required by the logic contained in the logic box is 770 ma, which is less than the 1 Ampere capability of the 597 module. A ± 6 volts D.C. requirement is generated by the incremental shaft encoder. Some supply voltage was also required by the LED used to generate the reference synch signal, and here the +6 volts D.C. is also used. The total current requirements are 500 ma at +6 VDC and 45 ma at -6 VDC. The two 6 volts supplies are similar, and are located on printed circuit cards in the logic box. A transformer with a 115 VAC primary and two 12 VAC secondaries which are rectified is used to generate ± 10 VDC. The ± 10 VDC is regulated to ± 6 VDC by two integrated circuit regulators. The output of the regulators drive a transistor to provide the current capability required.

Chopper Drive

Two blackbodies exist in the system; each is chopped by a mechanical chopper which is motor driven. The source chopper motor is a variable speed D.C. motor, while the reference chopper motor is a A.C. synchronous motor having a nominally fixed speed. Thus, two different methods are used to drive the motors. The reference chopper is fixed in frequency and a synchronous motor is used because this yields the greatest frequency stability. Frequency stability is imperative when the signal generated will be amplified in a narrow band system which is the case in this system. The reference chopper motor requires 115 volts, 400 Hz, 40 watts for nominal operation, which its frequency may be adjusted ± 10%. Adjusting the frequency sacrifices efficiency and hence power requirements increase but this enables the avoiding of troublesome 60 Hz harmonics. The drive for the reference chopper motor is provided by a circuit called the chopper motor drive located in the strip chart recorder chassis. This circuit first rectifies the 115 volt 60 Hz line and then Silicon Controlled Rectifiers (SCR) and a resonant circuit are used to generate a 115 volt 400 Hz power for the motor drive. The frequency of the SCR operation is controlled by an adjustable unijunction oscillator which is quite stable. The result is a sine wave stable in frequency, adjustable around 400 Hz, and with sufficient power output to drive the reference chopper motor. A switch called REF. OSC. located on the control panel is an on-off switch for this circuit.

The source chopper is driven by a D.C. motor which sacrifices the inherent stability of A.C. synchronous motors for variable speed control. Source chopper frequency in this system is variable from 30 to 3000 Hz. This design feature is incorporated for the purpose of potentially using the instrument for a study of atmospheric scintillation effects versus chopper frequency. An Electro-Optical Industries Model 311 modulator is the equipment used as the source chopper. A sophisticated closed loop servo technique provides stability of 0.25% which is quite good for D.C. motors and adequate for this system.

Blackbody Heaters

Each of the two blackbodies used in the system has a Electro-Optical Industries Model 216A temperature controller associated with it. The purpose of the controller is to provide a heating current to the resistive heaters located in the cavity. Heating current is proportional to the difference between cavity temperature and the temperature set point selected on the controller panel. A radiometric probe (silicon cell) located in front of the cavity is used as the sensing element. The probe output is a D.C. signal which is a function of temperature, which, is differentially amplified against a D.C. voltage also a function of the temperature setting. The differential output is further amplified and used to drive a power amplifier which has the cavity heater as its load.

4.0 COMPONENT DETAILS

In contrast to the last section which described system considerations and component interrelationships, this section provides details of individual components. Again, there are three main sections: optical, mechanical and electrical components. A given component may appear in more than one section. For example, the detector is principally an optical device and some of the description of the detector is in the optical section. Detector mounting details are given in the mechanical section, however, and biasing details, etc., are given in the electrical section.

Wiring tables in Section 8.0 are the prime source of information for electrical connections and the figures given are intended to augment these tables.

Except for electrical interconnections the drawings are the prime source of detailed information and the figures given are again intended to augment these drawings. Reduced size reproductions of the drawings are included in Section 9.0 of this report.

4.1 Optical Components

The components which are primarily optical in nature are the blackbodies, telescopes, reference optical system, monochromator, detector optical system detector and synch receivers. For the most part optical component details are given in this section; there are exceptions and, in these cases, reference is made to the appropriate section of this report.

4.1.1 Blackbodies

The source and receiver blackbodies subsystems are nominally identical units built by Electro Optical Industries of Santa Barbara, California. The optical details of the blackbodies have already been described in Section 3.4.1 in connection with the relation of the blackbody cavity to the beam boundaries.

Mechanical details of the blackbody housing geometry and plumbing are given in Section 4.2.4. Operational procedure is given in Section 5.1.1.

Numerous blackbody heater failures have occurred during construction of the ROSE system. The manufacturer states that the cavity heaters have been modified to give a reasonable life, ca. 700 hours or so.

After each return from the manufacturer the blackbody settings are determined for a temperature of about 1800°K. This is done by means of an optical pynometer (L&N Model 8622-C) which is calibrated to standards traceable to the National Bureau of Standards. The accuracy of the instrument is believed to be about ± 10 degrees C and the precision of measurement is estimated (from the mean deviation of about ± 1.3°C of the difference between readings approaching the point of brightness balance from above and below) to be $3\sigma \sim \pm 6$ degrees C.

Since there is a temperature gradient across the cavity particularly along the length of the opening, the center temperature is usually monitored during warm-up conducted according to the manufacturers instructions. After the center temperature has stabilized, readings are made at five locations by means of a small hole placed infront of the cavity; otherwise balance is difficult to judge. Two readings are made at the cavity ends; one at each end of the cavity with the hole approximately tangent to the cavity opening. One reading is made at the center and two intermediate readings are made; one about halfway between the center and each end. It is important to place the pyrometer squarely in front of the cavity.

Data taken for one such test are shown on Figure 4.1.1.1 during warm-up. From the semilog plot it is estimated that the warm-up time to the point where the temperature difference from the final temperature equals the variations in final temperature is about 90 minutes.

The spatial profiles of temperature along the length of the cavity opening for a typical test are shown on Figure 4.1.1.2. The spatial variation after the last rework of the reference blackbody is much less than that shown here (because a different winding procedure was used, according to the manufacturer). Since operationally the entire cavity is not used the average of the three central readings is taken to be representative of the cavity temperature. Settings are adjusted so that these average temperatures are nearly equal for the source (S/N 155) and receiver (S/N 154) blackbodies. Usually this can be done with one or two trial settings to within the precision of the temperature measurements. Because of the time required for temperature stabilization this procedure usually requires one long day.

Numerous blackbody heater failures have occurred during construction of the ROSE system. The manufacturer states that the cavity heaters have been modified to give a reasonable life, ca. 700 hours or so.

After each return from the manufacturer the blackbody settings are determined for a temperature of about 1800°K. This is done by means of an optical pyrometer (L&N Model 8622-C) which is calibrated to standards traceable to the National Bureau of Standards. The accuracy of the instrument is believed to be about ± 10 degrees C and the precision of measurement is estimated (from the mean deviation of about ± 1.3°C of the difference between readings approaching the point of brightness balance from above and below) to be $3\sigma \sim \pm 6$ degrees C.

Since there is a temperature gradient across the cavity particularly along the length of the opening, the center temperature is usually monitored during warm-up conducted according to the manufacturers instructions. After the center temperature has stabilized, readings are made at five locations by means of a small hole placed in front of the cavity; otherwise balance is difficult to judge. Two readings are made at the cavity ends; one at each end of the cavity with the hole approximately tangent to the cavity opening. One reading is made at the center and two intermediate readings are made; one about halfway between the center and each end. It is important to place the pyrometer squarely in front of the cavity.

Data taken for one such test are shown on Figure 4.1.1.1 during warm-up. From the semilog plot it is estimated that the warm-up time to the point where the temperature difference from the final temperature equals the variations in final temperature is about 90 minutes.

The spatial profiles of temperature along the length of the cavity opening for a typical test are shown on Figure 4.1.1.2. The spatial variation after the last rework of the reference blackbody is much less than that shown here (because a different winding procedure was used, according to the manufacturer). Since operationally the entire cavity is not used the average of the three central readings is taken to be representative of the cavity temperature. Settings are adjusted so that these average temperatures are nearly equal for the source (S/N 155) and receiver (S/N 154) blackbodies. Usually this can be done with one or two trial settings to within the precision of the temperature measurements. Because of the time required for temperature stabilization this procedure usually requires one long day.

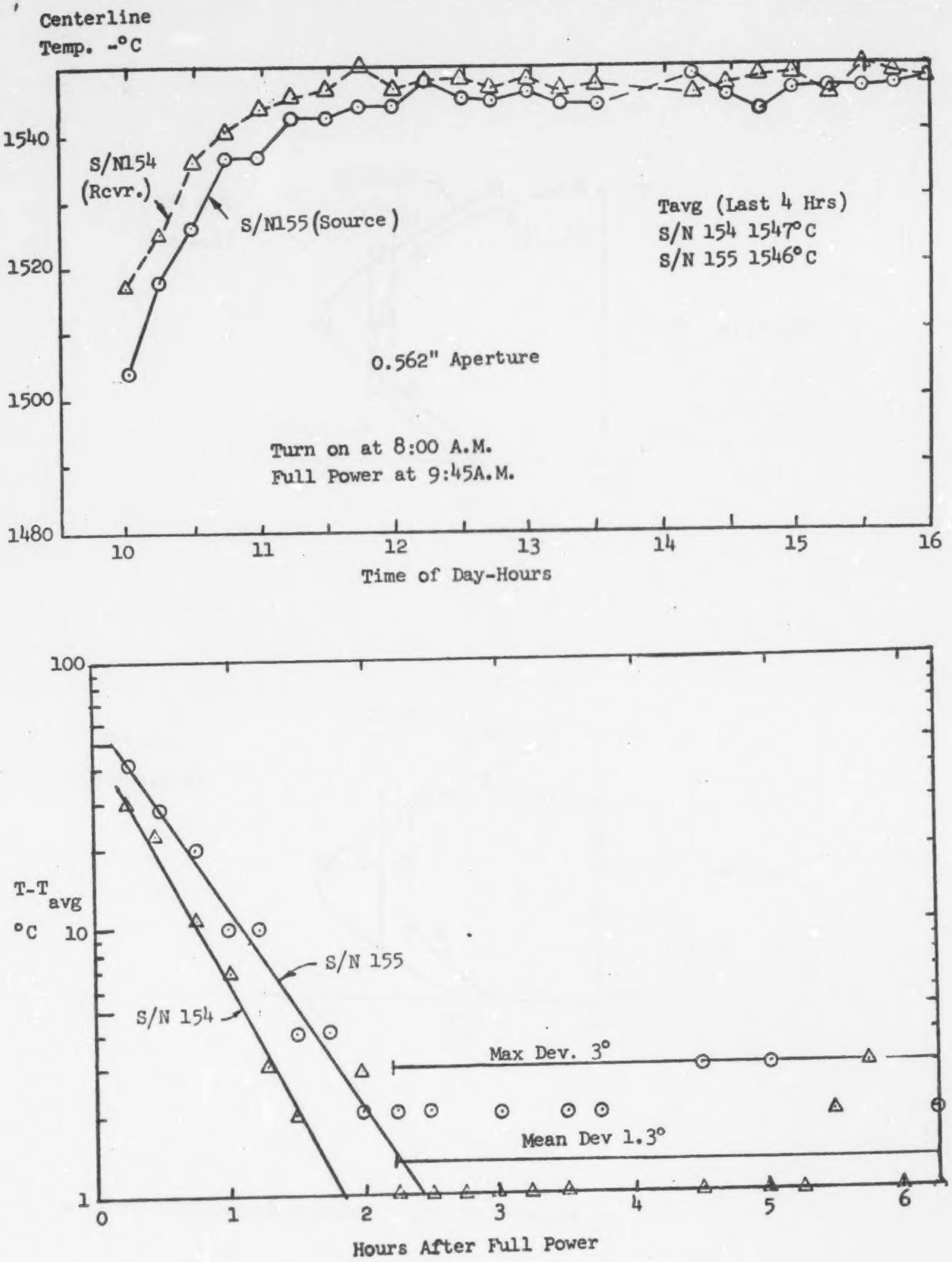


Figure 4.1.1.1. Blackbody Warmup History

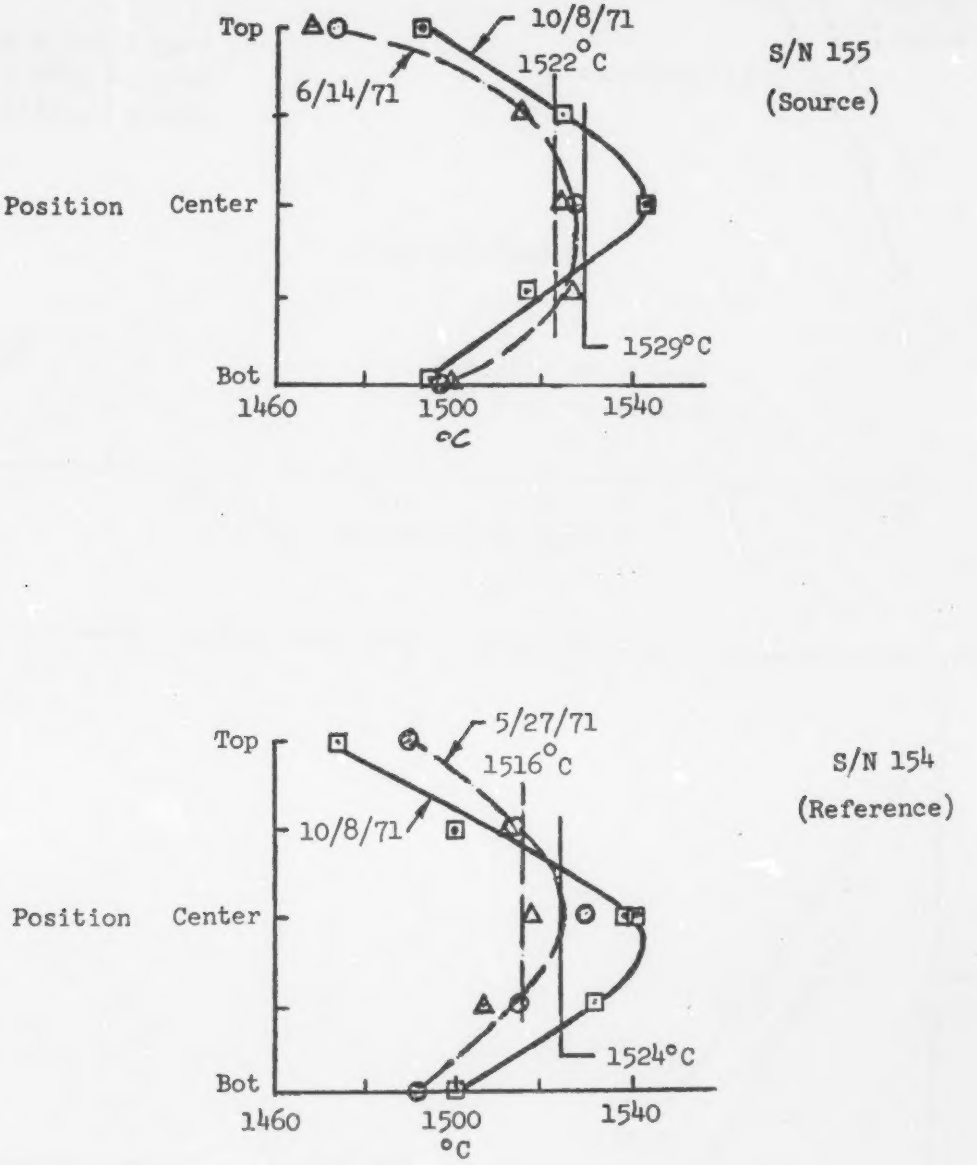


Figure 4.1.1.2. Blackbody Temperature Profile

4.1.2 Telescopes

The source and receiver telescopes are nominally identical Model 700 units made by Perkin Elmer, Costa Mesa, California. Each telescope consists of a concave ellipsoidal primary mirror with a central hole and a smaller convex spherical secondary mirror. This combination is commonly referred to as a Dall-Kirkham system. The basis for selecting this system is given in Section 3.4.2.

Figure 4.1.2.1 gives a reduced size reproduction of the manufacturers optical diagram of the telescope.

The optical specifications for the f/5 120 inch focal length Dall Kirkham telescopes are:

Flat Object Plane

Total field of view = 0.25 degrees
Distance Infinity

Primary Mirror

Diameter = 24 inches
Axial radius of curvature = 96.0 inches
Central obscuration = 9.5 inches
Axial separation (to sec.) = 30.0 inches
Conic constant (elliptical) = -0.559

Secondary Mirror

Diameter = 9.5 inches
Axial radius of curvature = 60.0 inches
Axial separation (to image) = 45.0 inches
Conic constant (spherical) = 0

Flat Image Plane

Maximum distance from axis = 0.2512 inches
Distance (from pri vertex) = 15.0 inches

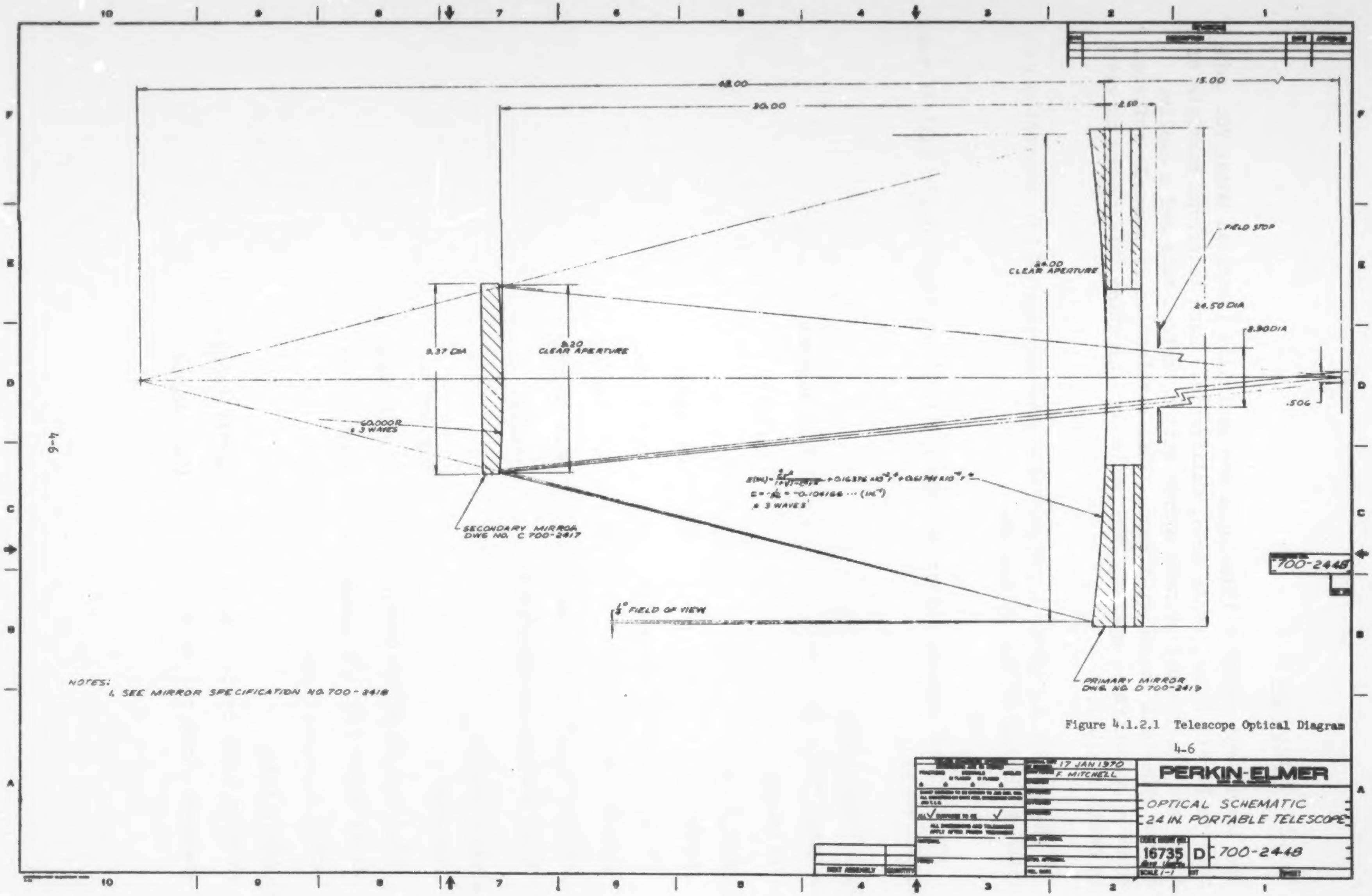

48.00
30.00
15.00
2.50
24.00 CLEAR APERTURE
FIELD STOP
24.50 DIA
8.90 DIA
.506
9.37 DIA
8.20 CLEAR APERTURE
60.000R ± 3 WAVES
$Z(r) = \frac{\frac{c}{2}r^2}{1+\sqrt{1-c^2r^2}} + 0.16376\times10^{-5}r^4 + 0.61791\times10^{-9}r^6$
$c = -\frac{1}{96} = -0.104166\cdots (\text{IN}^{-1})$
± 3 WAVES
SECONDARY MIRROR DWG NO. C 700-2417
PRIMARY MIRROR DWG NO. D 700-2419
$\frac{1}{2}$° FIELD OF VIEW
NOTES:
1. SEE MIRROR SPECIFICATION NO. 700-2418
700-2448
17 JAN 1970
F. MITCHELL
PERKIN-ELMER
OPTICAL SCHEMATIC
24 IN. PORTABLE TELESCOPE
16735
D
700-2448
SCALE 1-1

Figure 4.1.2.1 Telescope Optical Diagram

Mechanical details of the telescopes are given in Section 4.2.5.

The theoretical optical performance has been calculated for one telescope (as used in the emission mode of operation) which is called the Dall-Kirkham System and for two telescopes facing each other (as used in the transmission mode of operation) which is called the Telescope System. The results of these calculations using the POSD program are shown on Figure 4.1.2.2 for the Dall-Kirkham System and Figure 4.1.2.3 for the Telescope System. These figures show spot diagrams at the focus of the receiving telescope in each case. (Corresponding to the monochromator entrance slit location.)

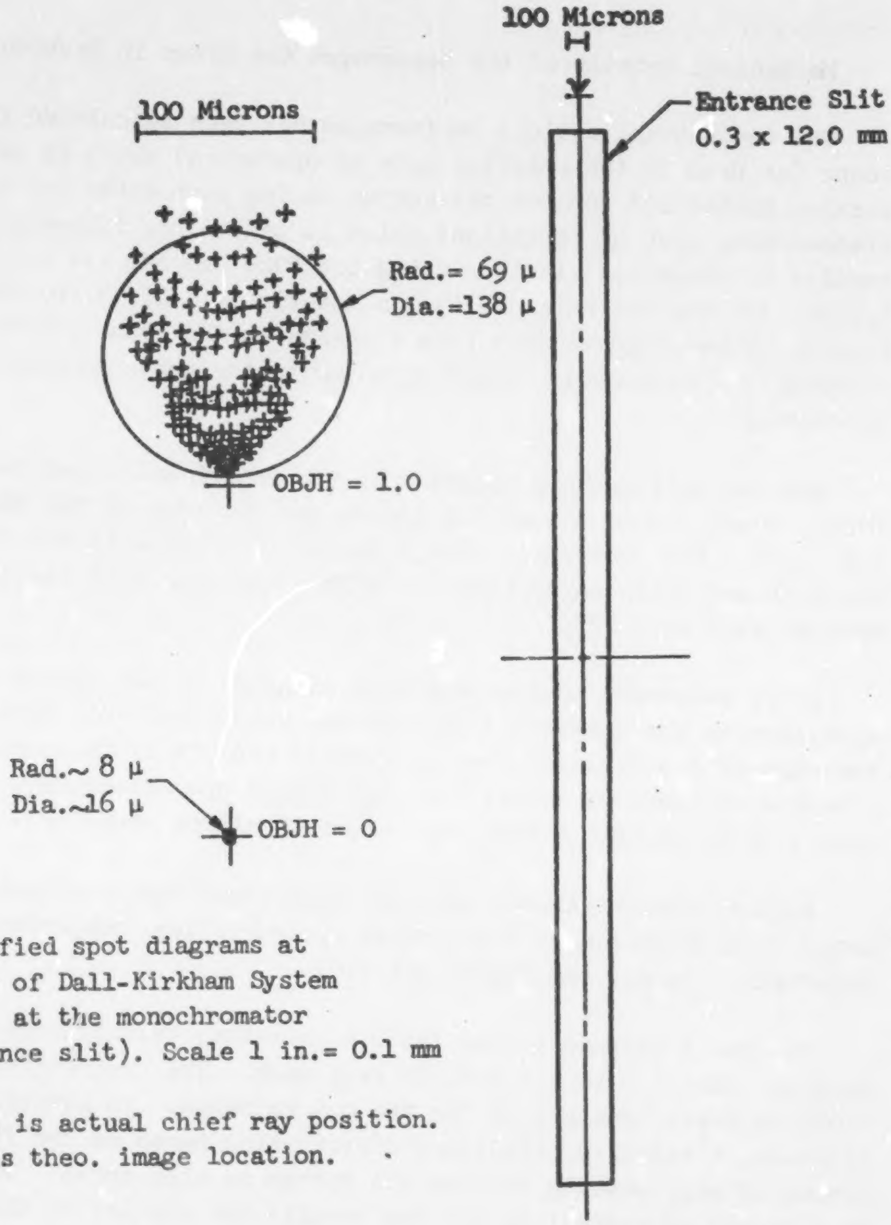
For the Dall-Kirkham System only two fractional object heights were used, OBJH = 0 and 1.0, i.e., at the center and the edge of the field of view (94 rays). The theoretical image height from the axis was 0.251 inches (or 6.38 mm) which corresponds to OBJH = 1.0 or a half field angle from the optical axis of 0.12°.

It is necessary to show the spot diagrams on two scales to relate the spot size to the entrance slit size and still show spot detail. The image at the edge of the field of view is comatic and 90% of the energy lies within a radius of about 69 microns (or 138 micron spot diameter). The on-axis spot size is about 8 micron radius (or 16 micron diameter).

Further investigations were not made since the performance of the telescope in combination with the other system optical components is more important. (e.g., see Figure 3.4.5.6)

For the Telescope System (at 0.4 km range) calculations were made for object heights, OBJH = 0 to 1.0 with 48 rays each. The theoretical image height was 4.645 mm which equals $h_o/2$ for the 0.4 km range. In addition to the spot diagrams, a relative irradiance distribution based on the fraction of the number of rays passing through the system is also shown. This distribution is a result of vignetting and the results are similar to those obtained in a different manner, see Figure 3.3.2.6.

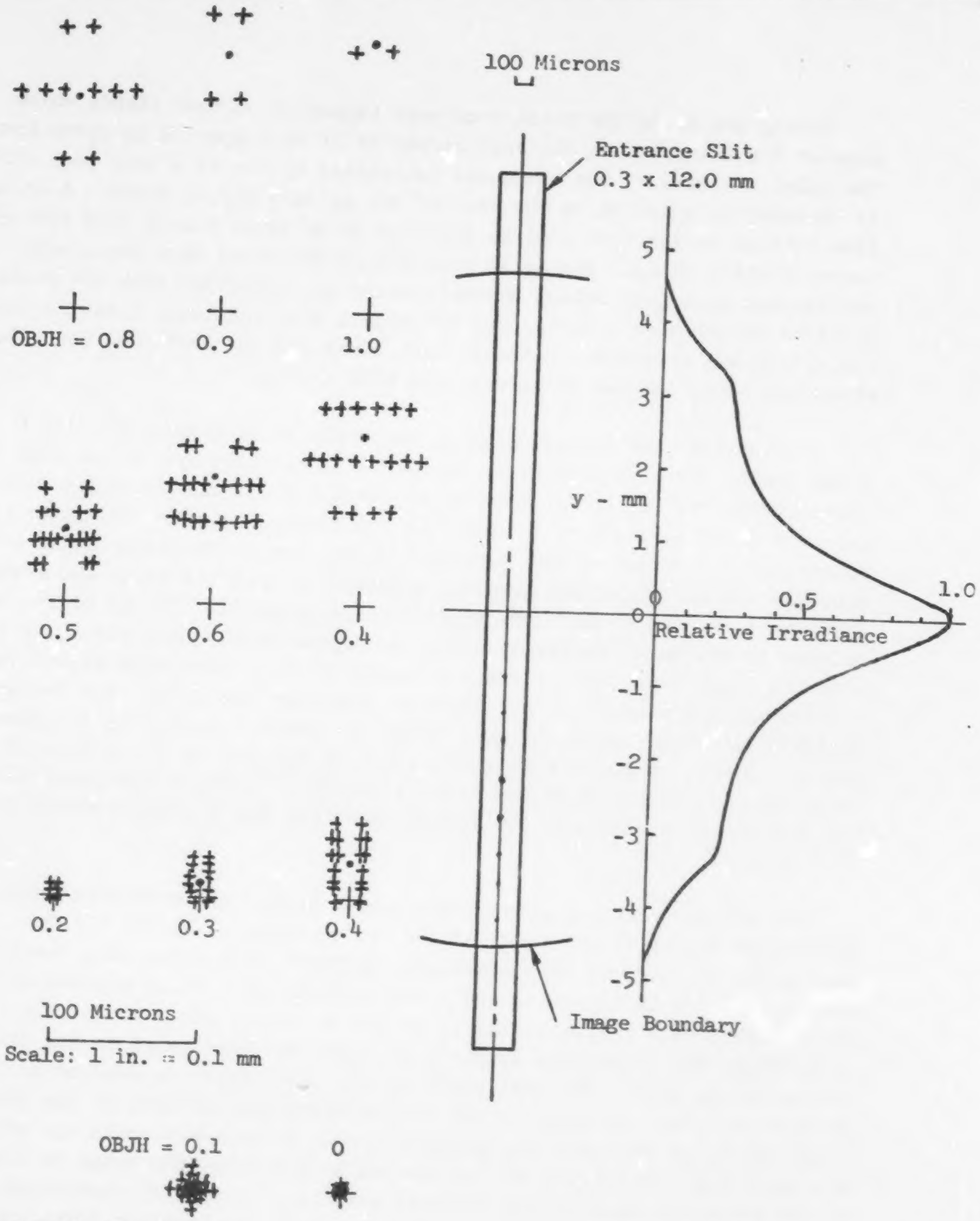
The telescopes were tested to determine the axial position of the image and the focal spot size within which 90% of the energy is enclosed. A distance of the focal spot from the telecope mounting plane was specified to be 12.00 ± .03 inches. The focal spot diameter was specified as 150 microns.



Magnified spot diagrams at
focus of Dall-Kirkham System
(i.e. at the monochromator
entrance slit). Scale 1 in.= 0.1 mm

Cross is actual chief ray position.
Dot is theo. image location.

Figure 4.1.2.2 Dall - Kirkham System Performance



Magnified spot diagrams at
focus of Telescope System.
Cross is actual chief ray position.
Dot is theoretical image location.

Range = 0.4 Km

Figure 4.1.2.3 Telescope System Performance

During the tests the telescopes were supported on test stands which support the telescope in the same manner as it is supported in operation. The axial position of the image was determined by use of a test tool which is threaded to screw on to the rear of the primary mirror mount. A cross line reticle on the test tool is adjusted to be 12.00 inches from the telescope mounting plane. The axial position of the focal spot for a well collimiated beam (see below) was determined by comparison with the reticle position by means of a microscope to which a dial indicator (reading axial distances) was attached. Both the test stand and the test tool described above are being shipped along with the ROSE system.

A telescope test source using an available 24 inch diameter, 152.6 inch focal length parabolic mirror, a 24 inch diameter flat mirror and flat diagonal mirror was set up as shown in Figure 4.1.2.4. The parabolic mirror axis was found by means of a laser and the diagonal mirror; the laser was pointed at the center of the parabolic mirror (with the beamsplitter assembly removed) and the laser and diagonal adjusted so that the going and return spots were aligned at both the laser and the diagonal. The 67 micron hole, mounted in the exact center of a hole in a precision square block,was aligned with the laser beam and was fully illuminated by a microscope objective with a uniformly illuminated ground glass at its long conjugate. The beamsplitter assembly was moved along the axis until the image reflected by the beamsplitter and observed by means of a microscope was at the face of the precision block. This places the pinhole on the axis at the focal point of the parabolic mirror and results in a precisely collimated beam from the parabolic mirror to the flat mirror.

The effective source size of the source system was evaluated using a photometer at the return focus of the system shown on Figure 4.1.2.4. The photometer was made up from available equipment consisting of a Gaertner miscroscope (32 mm objective and a 10X eyepiece in a filar micrometer), a photographic lens (Zeiss Biotar 58 mm f/2 to f/16), and a photomultiplier (RCA 7265). The microscope eyepiece projects the test image on the diaphragm of the Biotar lens. The exit pupil of the test object is focused on the photomultiplier. By changing the Biotar diaphragm the size of the image from which energy is received may be controlled. An arbitary scale was attached to the diaphragm control and was calibrated by measuring the image of the diaphragm at the telescope image plane using an auxiliary micrometer microscope. For this calibration a diffuse source was placed in the location normally occupied by the photomultiplier. Focus was obtained with both the filar cross hairs and diaphragm edges in focus. The calibrated image size range was from 74 to 664 microns.

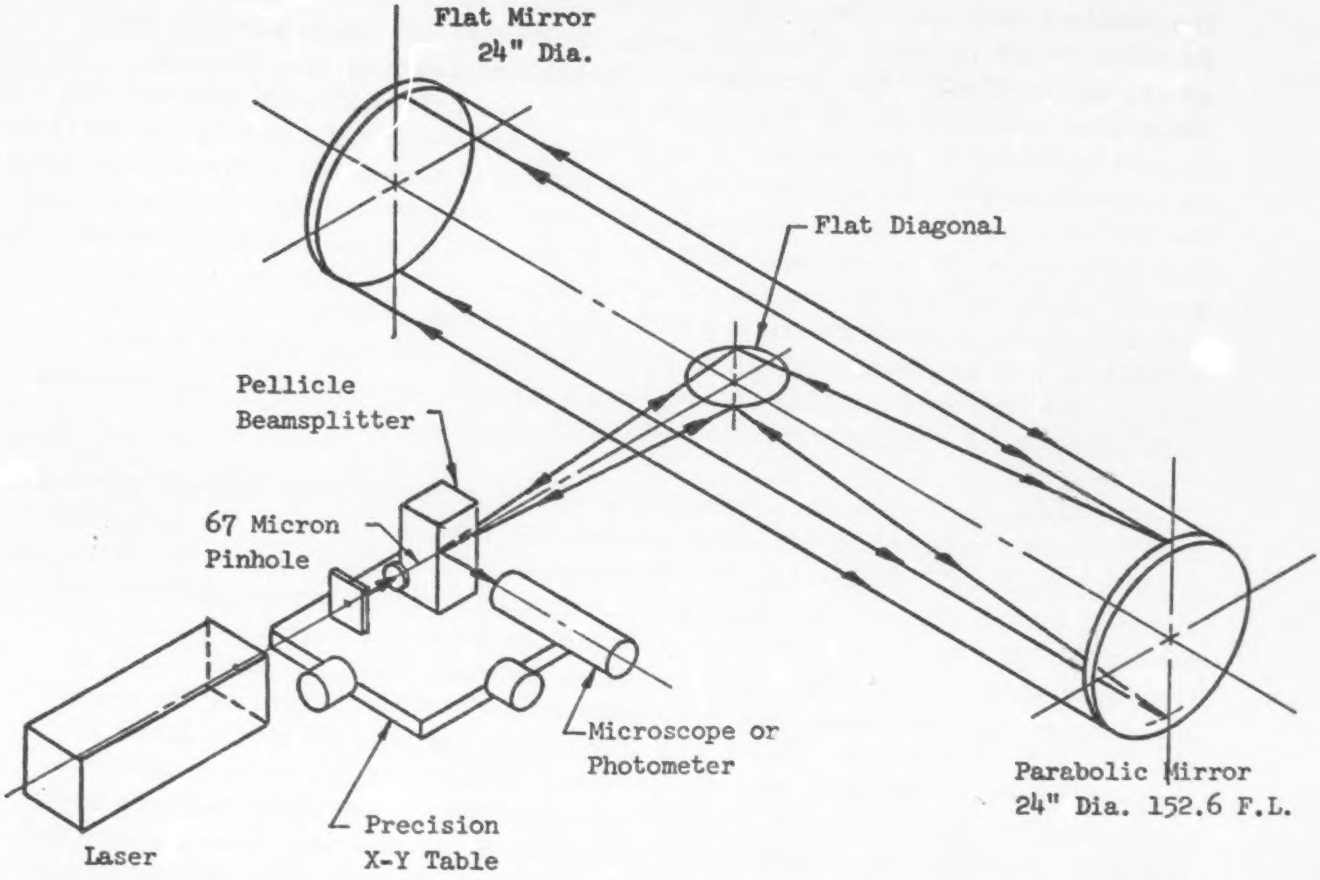


Figure 4.1.2.4 Telescope Test Source

A chopper was installed between the light source and the pinhole, and photometer readings were taken on a Princeton HR8 lock-in amplifier for various diaphragm settings after first centering the photometer for maximum signal with the smallest aperture. The energy with the wide open aperture was taken as 100%. From the resulting curve of output versus image size the image size for 90% energy was obtained. The correction to be applied later to the telescope image size observations for the finite source size and collimator imperfection was evaluated by taking photometer readings on the image reflected by the pellicle in autocollimation. It was found that the parabolic mirror had a turned edge and was not precisely parabolic although the figure was smooth. Measurements at the full aperture of 24 inches and at 20 inches gave 90% energy spot sizes of 380 and 270 microns, respectively in autocollimation. It can be shown that in autocollimation a slope defect produces double the displacement of a single reflection. Thus for the telescope focal length of 120 inch the 90% energy size of the source is (380/2)(120/152) = 150 microns for a 24 inch aperture and (270/2)(120/152) = 107 microns for a 20 inch aperture.

The telescope test source (consisting of the parabolic and diagonal mirrors, the 67 micron pinhole and the light source) was used to evaluate the telescope image as shown in Figure 4.1.2.5. The laser was first set up (with the telescope removed) on the axis of the parabolic mirror behind the telescope position by making the spot returned from the center of the parabolic mirror coincide with the laser source. The telescope mounted on the test stand was then placed in position so that the laser beam was centered on the crossed wires at the center the telescope field mask. (The field mask center was used by Perkin Elmer in their alignment). The test tool was attached to the threaded primary mirror mount in which the field mask is mounted. The threads and field mask are concentric. A reticle on this tool was placed on the thread axis by adjusting the reticle laterially on the tool until no motion was observed with the microscope when the tool was rotated on the telescope threads. The reticle was then placed at the specified distance behind the mounting plane. The telescope axis is now defined by the reticle and crossed wires at the center of the field mask. The telescope was aligned to the collimated beam by placing the center of the field mask (defined by the crossed wires) on the laser beam and rotating the telescope until the telescope image fell on the reticle cross lines.

The telescope image was evaluated by placing the photometer behind the telescope focus and aligning it as described before. Image evaluations were made on the axis and at the edge of the specified ± 0.125 degree field of view which corresponds to about ±0.25 inch at the telescope focus.

The results of the photometer tests are as follows:

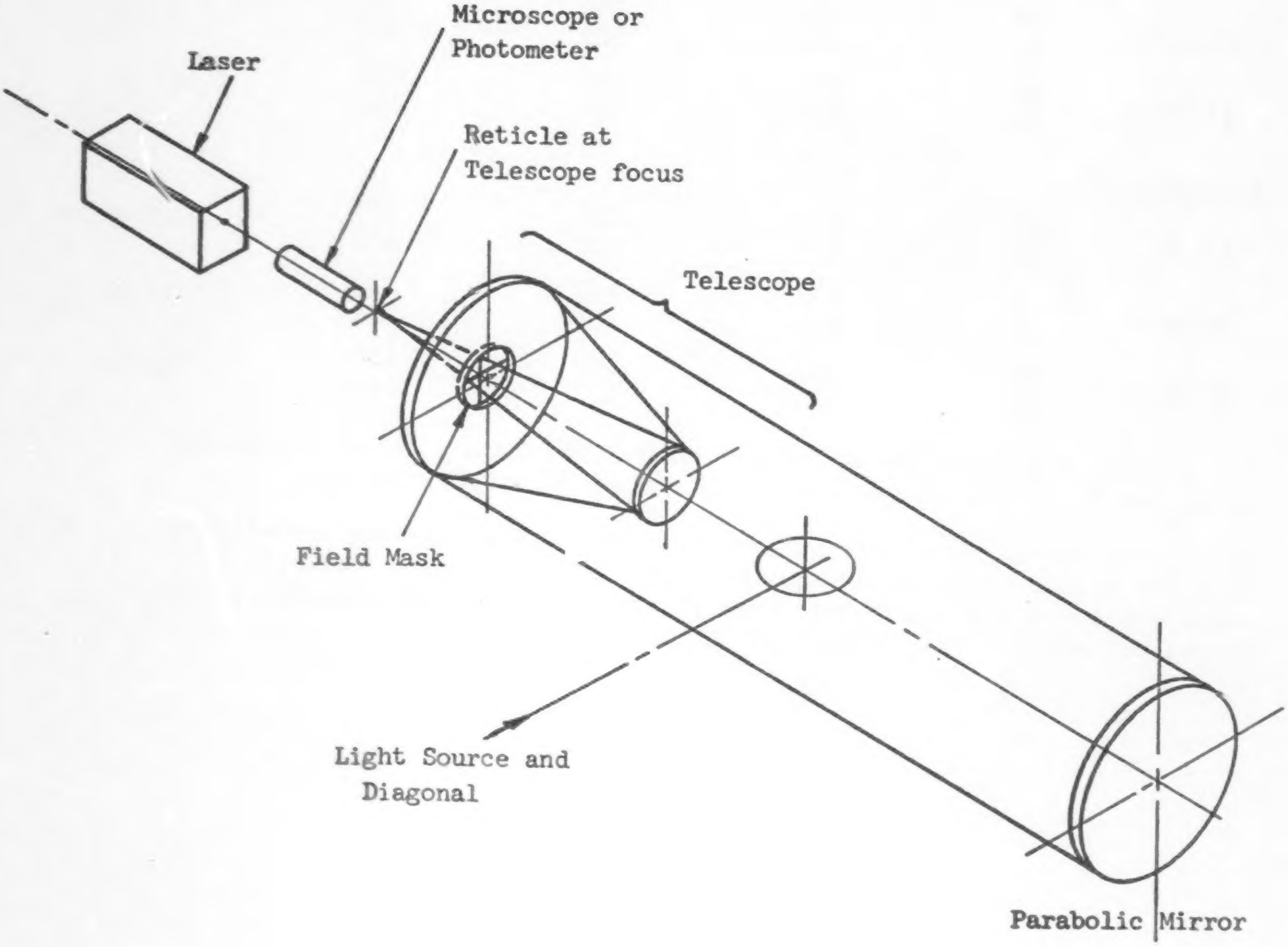


Figure 4.1.2.5 Telescope Test Set - Up

Telescope #1

Location	Parab. Aper.	Obs. 90% Image	Eff. Source	90% Image Size	Axial Pos.
¼" Up	24"	290 Microns	150 Microns	140 Microns	11.96 in.
	20	235	107	128	
On Axis	24	280	150	130	11.97
	20	225	107	118	
¼" Down	24	285	150	135	11.97
	20	247	107	140	
Telescope #2					
¼" Up	24"	280	150	130	12.00 in.
	20	270	107	163	
On Axis	24	280	150	130	12.00
	20	230	107	123	
¼" Down	24	312	150	162	12.03
	20	310	107	203	

The average difference in 90% image size for the 20 and 24" apertures for telescope #1 was 10 microns and for telescope #2 was 27 microns.

In view of the magnitude of the effective source size and the uncertainty of these values it is considered that both telescopes are acceptable for image quality (even though telescope #2 at the ¼" down position may slightly exceed the specification values of 150 microns).

4.1.3 Reference Optics

The reference optical system (except for the blackbody and the toroid) was built by Convair and is described on drawing 596-722-010. The optical components for the reference optical system are shown on drawing 596-722-007. The system provides a reference beam for the system as described in Section 3.4.3.

There are three glass mirrors in the reference optics system plus the chopper which also has a mirror surface on the side nearest the monochromator (see figure 4.1.3.1). Each surface is aluminized with a quarter-wave (visible) protective coating of SiO.

The reference beam starts at the reference blackbody. One conjugate focus of the spherical mirror is located at the middle of the front plate of the blackbody outer housing, the other conjugate focus (at unity magnification) is located at the intermediate focus. The beam is turned by means of the flat diagonal mirror between the spherical mirror and the intermediate focus. A toroidal mirror (60 degrees off-axis) is used to transfer the beam from the intermediate focus to the entrance slit. The chopper inclined at about 45 degrees serves to turn as well as chop the reference beam.

As indicated in the optical diagram all of the elements of the reference optical system are sized so as not to limit the reference beam. The apertures are the entrance slit and the mask on the grating in the monochromator.

The reference chopper is considered part of the reference optical system. The 304 stainless steel blade was made from a blank gear. The blades were milled on one set-up after which the blade was polished using stainless steel inserts to fill the gaps between the blades. Finally, it was aluminized and overcoated with SiO.

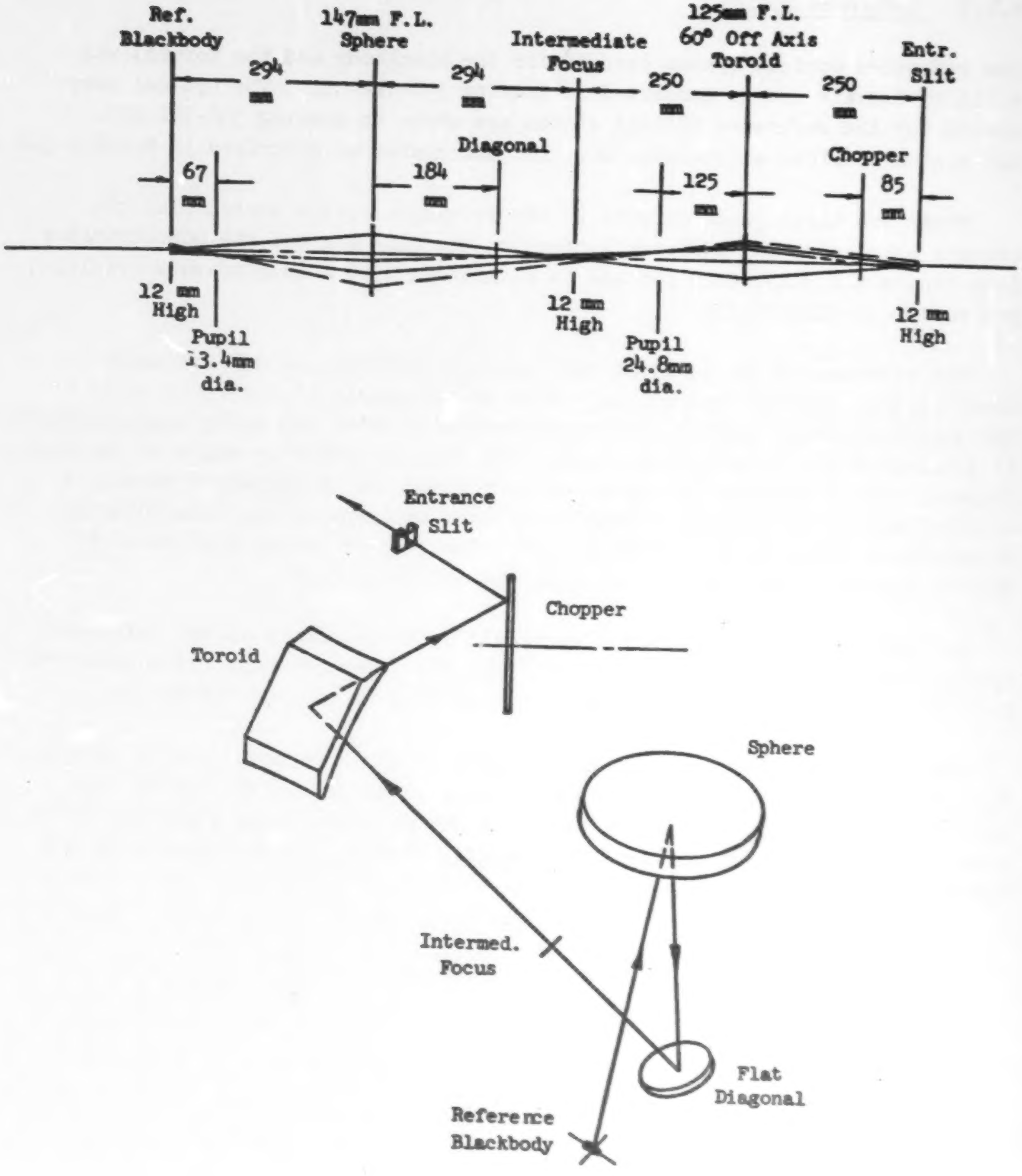


Figure 4.1.3.1 Reference Optics Diagram

4.1.4 Monochromator

The monochromator is a Model 210B made by Perkin Elmer, Norwalk, Conn. with a number of modifications made by Convair. This section will be devoted mainly to the modifications. An optical diagram of the monochromater is shown on Figure 3.4.4.1 which is the best estimate of its configuration since an optical layout was not available from the manufacturer.

Mechanical details of the monochromator mounting and mechanical modifications are described in Section 4.2.7.

The monochromator is an off-axis Littrow design using two interchangeable gratings. The grating data taken from the labels on the back of the grating is as follows:

Part No. 032-1006	Serial No. 01-1-6-G
240 grooves/mm	Blaze Frequency
Blaze Angle 20°	Blaze Wavelength 3400 cm^{-1} *
Blaze →	

* obviously in wrong place (1/3400 = 2.941 microns)

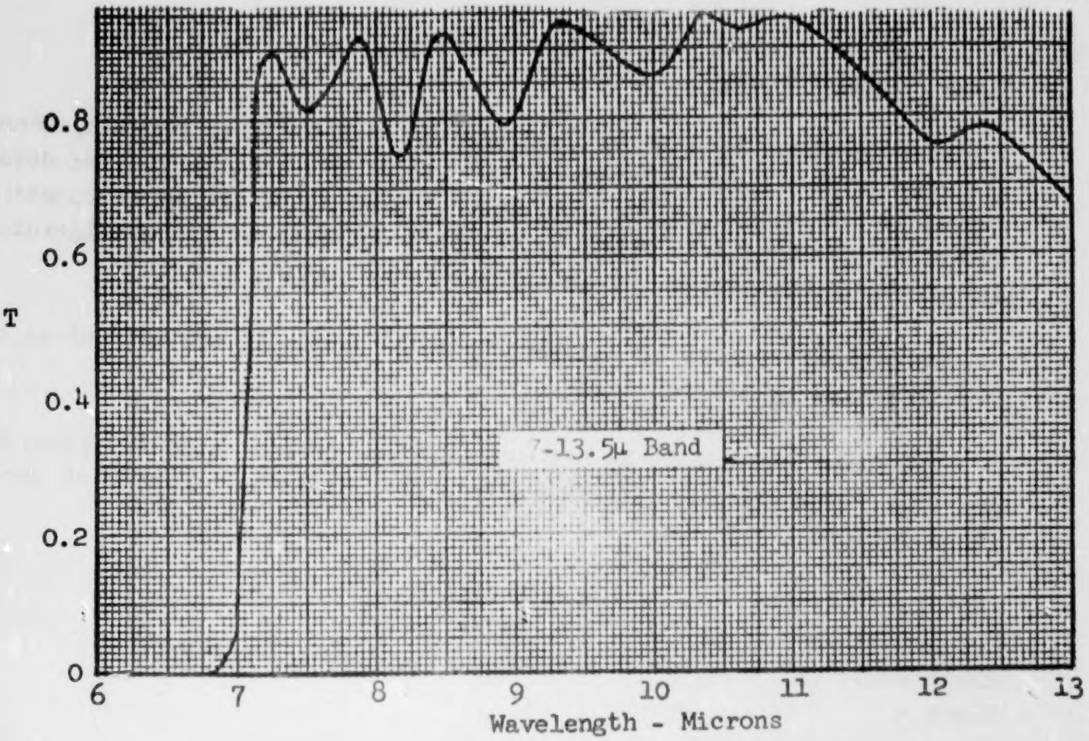
Part No. 032-1005	Serial No. 02-11-8-F
101 grooves/mm	Blaze Frequency
Blaze angle 22°-2'	Blaze Wavelength 7.5 microns
Blaze →	

Access to the grating change control is obtained by removing the round cover on top of the monochromator; the grating control is spring loaded in the up position. Pushing down on the control allows engagement of a pin on the grating mount. Then, by turning the control gently the grating mount can be rotated to place the desired grating in position. The contact at the end of the rotation is by means of a magnet on the grating mount which positions the grating precisely against stops at each end of the rotational range of travel.

There are two long wave pass filters provided, one for use with each grating. Curves of the transmission of these filters are given in Figure 4.1.4.1.

The filter may be changed by means of a knob on top of the monochromator. Four positions are plainly labelled: open, 3-5.5 micron, 7-13.5 micron, shut.

One optical modification of the monochromator has already been discussed in Section 3.4.4, namely the removal of a mask on the collimating paraboloid. It restricted the available aperture and, as shown in Section 3.4.4, was not necessary in the present case.



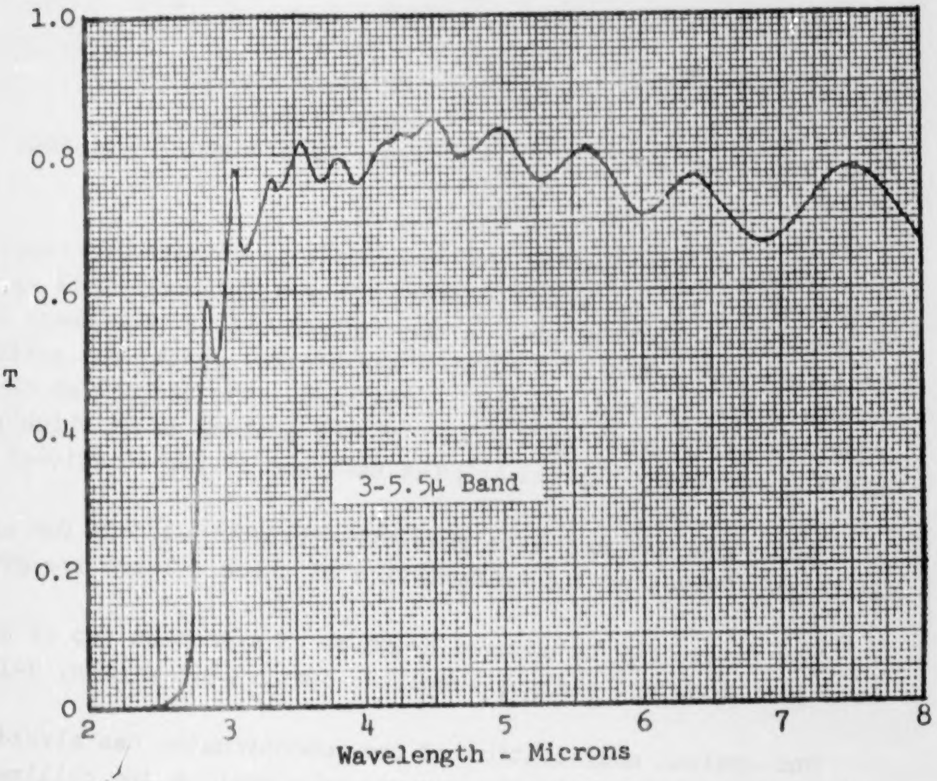


Figure 4.1.4.1 Filter Transmission

Another modification described in Section 3.4.4, is the addition of a mask on the grating which serves as one of the apertures of the system. An outline of the mask is shown in Figure 4.1.4.2 below. The nominal mask open area is 15.9 cm^2; The measured mask open area 15.1 cm^2 for the 101 L/mm grating mask and 15.7 cm^2 for the 240 L/mm grating mask.

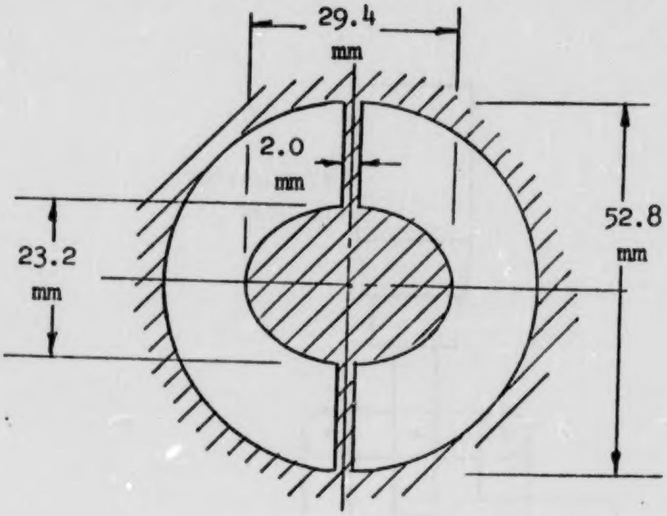


Figure 4.1.4.2 Grating Mask

Because of the large range of image size on the entrance slit it was necessary to add a slit height adjustment mechanism.

Since the space available close to the entrance slit is very limited a custom designed assembly was required. Figure 4.1.4.3 shows this mechanism schematically; for more details see drawing 596-722-012. Although this is a mechanical device its major function is optical and, therefore, will be described here. A parallelogram is actuated by a micrometer screw through a 2:1 ratio lever. The result is a bilateral opening slit whose width is nominally equal to micrometer reading if the zero's are properly set. Note that (in order to obtain direct reading) the micrometer closes the slit which is opposite normal practice; to prevent jamming the slit jaws, a stop was provided on the micrometer screw. Nevertheless, excessive torque on the micrometer should be avoided.

To prevent possible problems from sticking it is preferable to set this micrometer with a decreasing reading.

A hole in the monochromator cover permits convenient access to the slit height micrometer control. Care should be exercised in removing and replacing the cover not to place undue force on the micrometer.

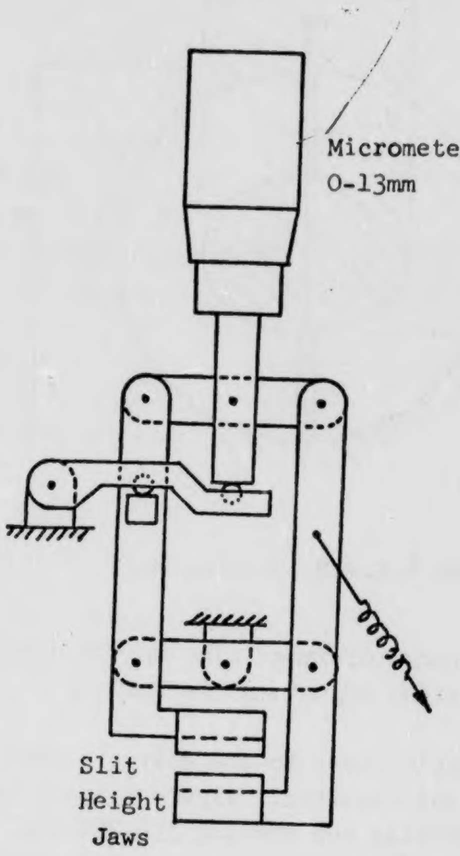


Figure 4.1.4.3 Slit Height Assembly Schematic

A field lens made of Irtran 2 (uncoated) was added (just ahead of the slit height adjustment assembly) which images the grating mask on to the telescope exit pupil. Since this pupil is the image of the telescope primary mirror formed by the telescope secondary mirror the grating mask is thereby imaged onto the telescope primary mirror. The grating mask image is the receiver telescope entrance pupil. The entrance slit of the monochromator defines the field of view of the receiver telescope.

No theoretical optical performance calculations were made for the monochromator alone. However, Figure 3.4.5.8 shows that addition of the monochromator had little effect on the Dall-Kirkham system optical performance with the Detector "Cassegrain". Consequently, the monochromator aberration contribution to the system is considered to be small relative to those of other components.

The entrance and exit slit jaw width was checked against the slit micrometer drum setting. A Gaertner microscope slide having 10 micron drum divisions with a 32 mm objective and a 10X eyepiece (overall ~ 40X) was used. The correction is defined as the slit width minus the setting. The maximum correction was 8 microns and the minimum correction was -13 microns for the exit slit. The mean correction for the exit slit was -3.6 micron (4.4 micron without regard for sign). For the entrance slit the maximum correction was 14 microns and the minimum correction was -7 microns; the mean correction was +1.9 microns (4.6 microns without regard for sign). The precision of setting on an edge was about ±1.5 microns so that the precision of a slit width measurements was about 2 to 3 microns. Thus, the corrections are not much more than would be expected from a normal error distribution and it is therefore recommended that corrections for the slit width be neglected. If more precise widths are required, measurements of the slit width should be made.

The slit height assembly was calibrated several times and as noted above, it was found best to set the micrometer with a decreasing reading. The same microscope as that used for the slit width measurements was used for these calibrations. The maximum correction was 0.038 mm and the minimum correction was -0.002 mm. The average correction was +0.021 mm. For slit heights above about 1 mm the corrections are less than 1% of the slit height. Therefore, it is considered that the slit height corrections may be neglected under normal conditions. If more precise values are needed a recalibration should be made.

A number of wavenumber calibrations have been made from time to time. Some of the earlier calibrations are no longer valid because the monochromator has been realigned by the manufacturer several times. The last alignment was made in December, 1970 and all data shown here were taken since that time.

There are a number of gases which are useful for wavenumber calibration; these are shown on Figure 4.1.4.4 at the spectral intervals for which each could be used.

The latest wavenumber calibrations are as follows.

240 L/mm Grating:

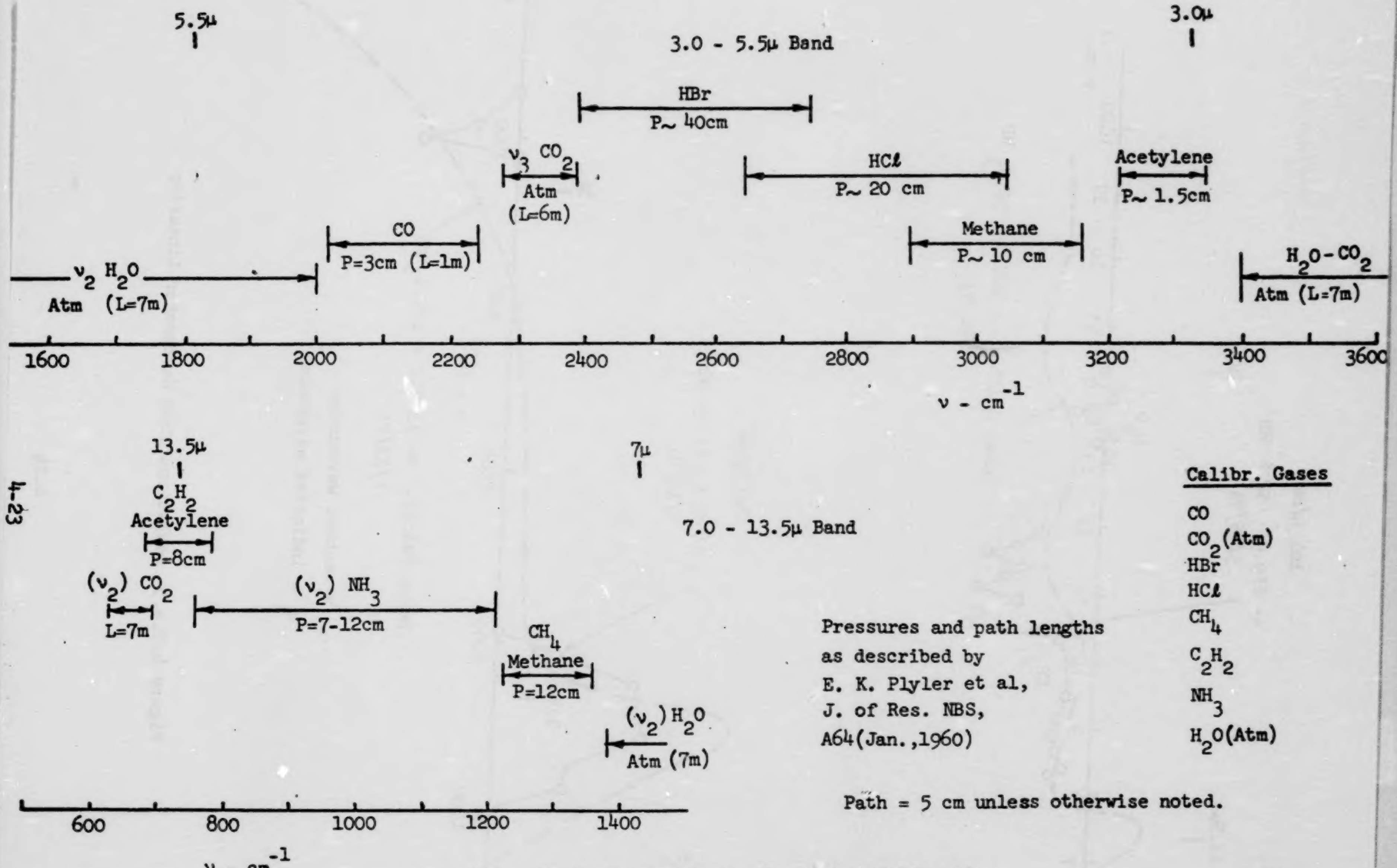
$$\nu = 1472.9 + 123.9 \text{ WD} \quad \text{cm}^{-1}$$

101L/mm Grating:

$$\nu = 619.9 + 52.2 \text{ WD} \quad \text{cm}^{-1}$$

where WD = no. of wavenumber drum turns

A discussion of set-up of these equations into the system is given in Section 3.5.2. Deviations from the above equations based on known molecular lines are given in Figure 4.1.4.5.



Pressures and path lengths
as described by
E. K. Plyler et al,
J. of Res. NBS,
A64(Jan.,1960)

Calibr. Gases

CO
CO_2(Atm)
HBr
HCℓ
CH_4
C_2H_2
NH_3
H_2O(Atm)

Path = 5 cm unless otherwise noted.

Figure 4.1.4.4 Gases Useful for Wavenumber Calibration

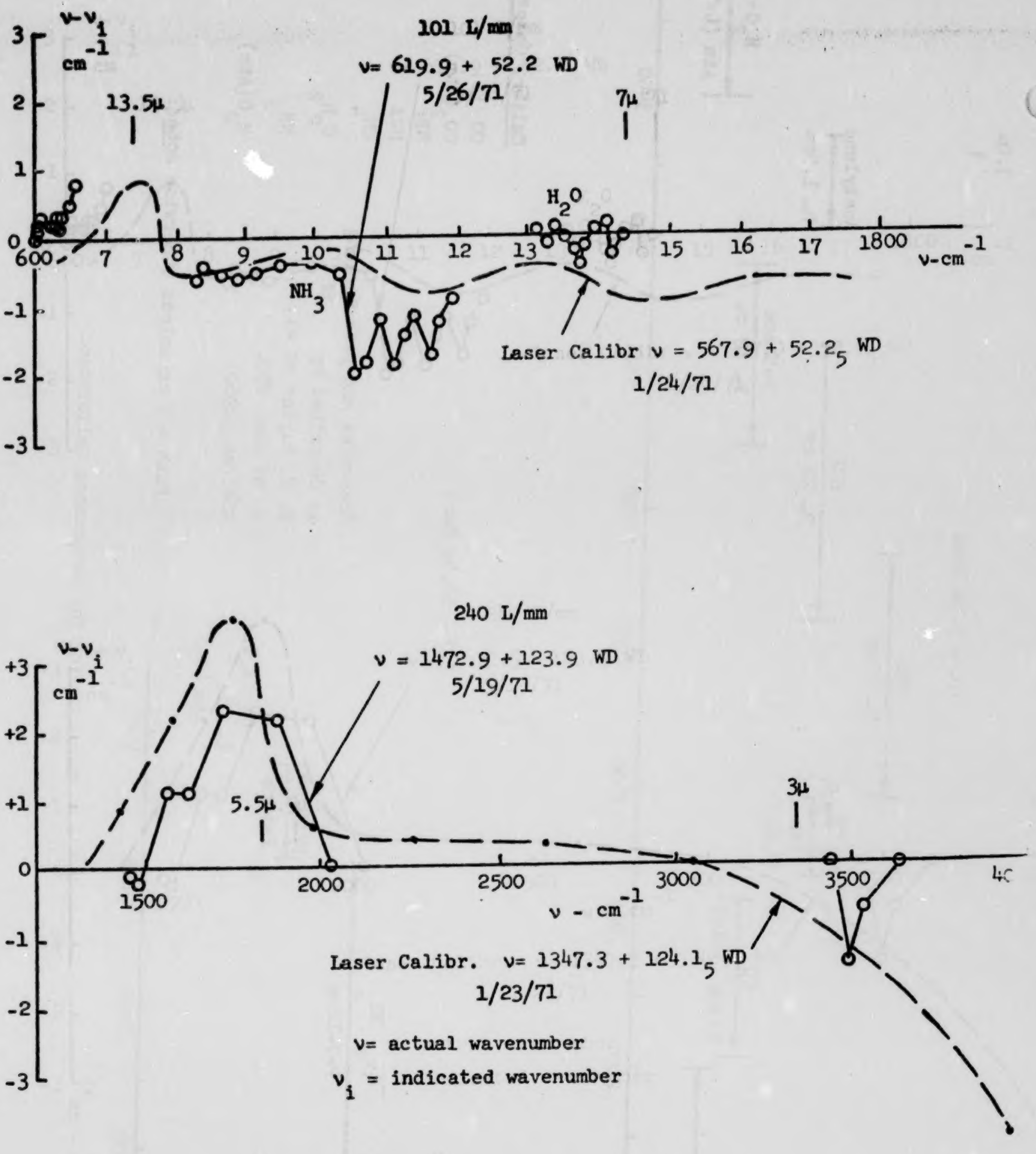


Figure 4.2.4.5 Deviations from Wavenumber Linearity

4.1.5 Detector Optics

The detector optical system was designed and built by Convair and is described on drawing 596-722-011. The optical components for the detector optical system are shown on drawing 596-722-008. Mechanical details are discussed in Section 4.2.8.

The detector optical system reduces the image at the monochromator exit slit by a factor of six. A toroid reduces the exit slit image by a factor of two and the remaining reduction of three is accomplished by the detector "Cassegrain" see Figure 3.4.5.1. The quotation marks indicate that the system is not strictly a Cassegrain system since it utilizes spherical surfaces. Nevertheless, the name is commonly applied to two mirror combinations of this sort and will be used here for convenience.

The theoretical performance of the detector optical system is most usefully given in combination with the other system optical components; this has already been shown in Section 3.4.5.

There are four mirrors in the detector optical system: a toroid, a flat, a convex secondary and a pierced concave primary mirror. All are aluminized and overcoated with SiO. In addition an uncoated Irtran 2 field lens is used to control off-axis rays by imaging the toroid exit pupil onto the "Cassegrain" center of curvature (the two "Cassegrain" mirrors have a common center of curvature).

An optical diagram of the detector optical system is shown in Figure 4.1.5.1. This optical diagram can be used for the optical alignment of the "Cassegrain" assembly by placing a small image on axis at the field lens surface, observing the image at the detector location and adjusting the Cassegrain ring until the sharp and symmetrical detector image distance is at the proper location. The location and size of the pupil just ahead of the detector is not well defined because of aberrations. Numerous rays were traced for a variety of conditions both with the Dall -Kirkham System (one telescope) and Telescope System (two telescopes). From all of these data it was decided that a detector mask corresponding to 10.0 mm diameter at 5.0 mm from the detector would be the best size and location; this gives an approximately 90° field of view at the detector.

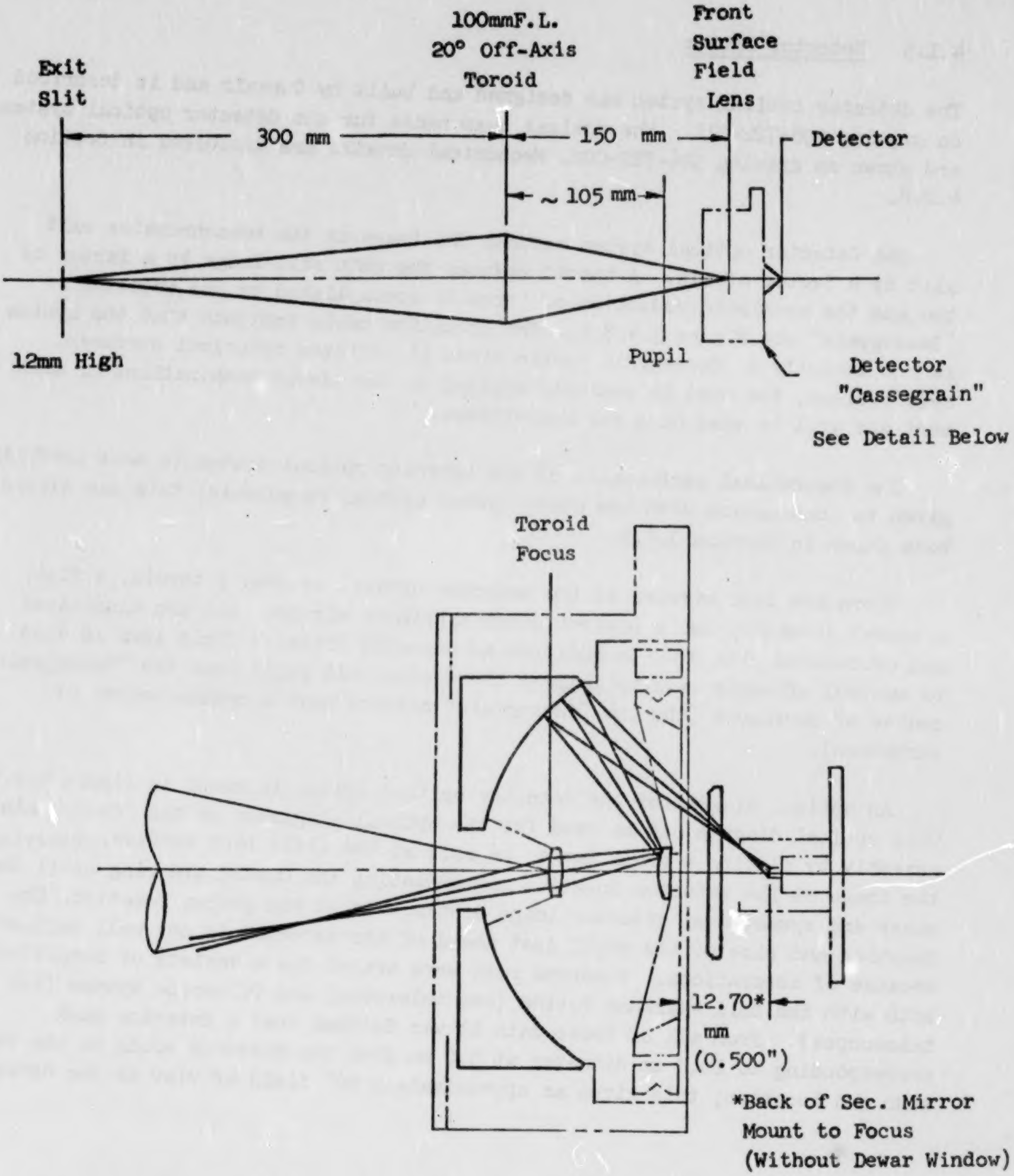


Figure 4.1.5.1 Detector Optics Diagram

4.1.6 Detector

The detector was supplied by Santa Barbara Research Center (SBRC) and is made of mercury-doped germanium (Hg:Ge). It is described by the following purchase specification and the specification drawing shown in Figure 4.1.6.1 (see also drawing 596-722-016).

The following specification (along with the Detector Specification drawing shown in Figure 4.1.6.1) was used for detector procurement.

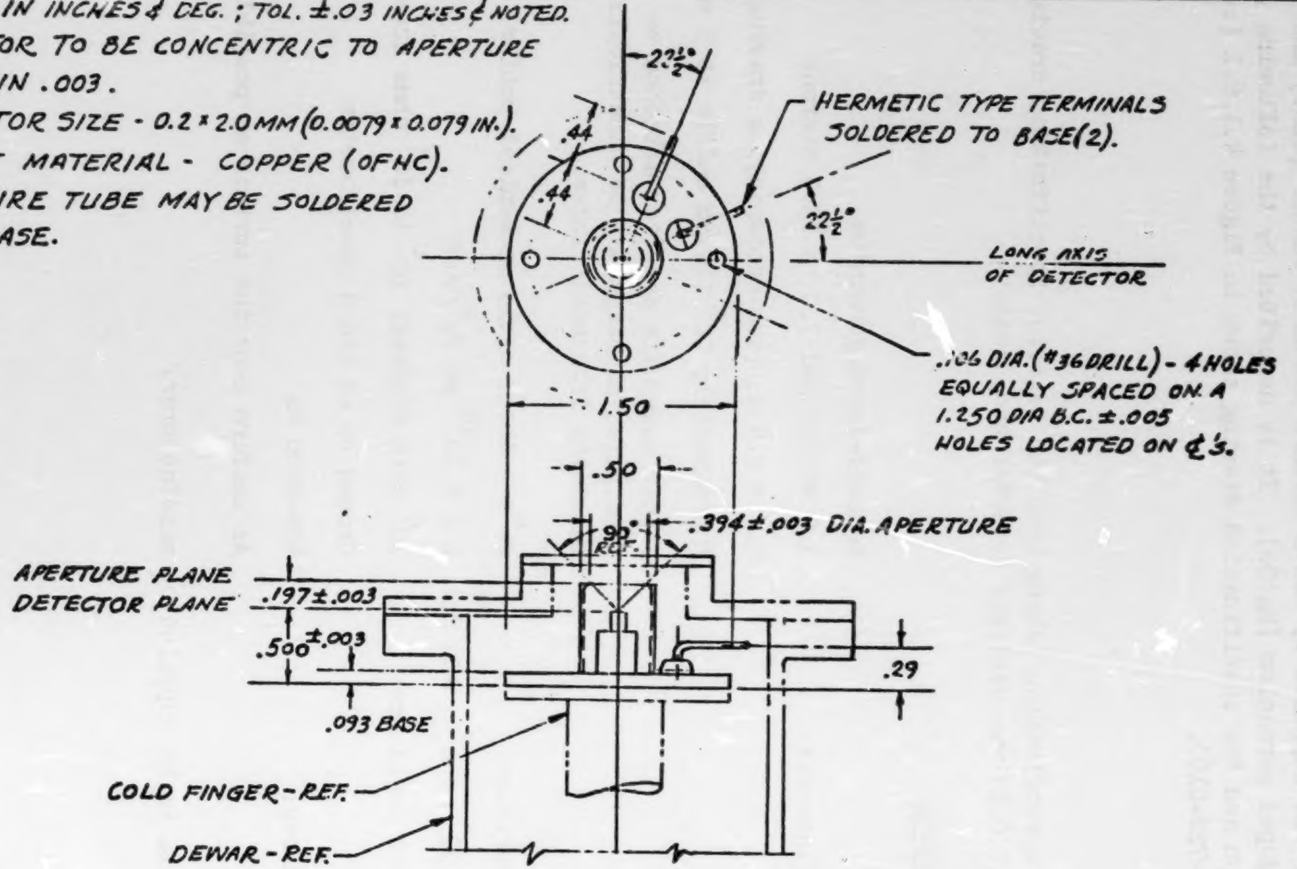
Detector Specification

Type	Mercury-doped germanium
Wavelength of Interest:	3.0 to 5.5 and 7.0 to 13.5 microns
Element Size:	0.2 × 2.0 mm (see accompanying drawing)
Field of View:	Approximately 90° (10 mm baffle at 5 mm)
Mounting:	Copper base with detector attached to terminals; mounting may be electrically insulated from cold finger.
Operating Temperature:	26°K (closed cycle mechanical cooler)
Blackbody D* (90°, 500°K, 400 Hz):	$\geq 1 \times 10^{10}$ cm Hz$^{\frac{1}{2}}$/watt
Effective Source Impedance:	10^{6} ohms nominal; 10^{4} to 10^{7} ohms acceptable
Application:	Ground based field spectrometer
Chopping Frequency:	400-2000 Hz
Responsivity:	As uniform over the surface as possible

Performance data to be supplied by manufacturer.

NOTES:

1. ALL DIM. IN INCHES & DEG.; TOL. ±.03 INCHES & NOTED.
2. DETECTOR TO BE CONCENTRIC TO APERTURE WITHIN .003.
3. DETECTOR SIZE - 0.2 × 2.0 MM (0.0079 × 0.079 IN.).
4. MOUNT MATERIAL - COPPER (OFHC).
5. APERTURE TUBE MAY BE SOLDERED TO BASE.



DO NOT SCALE DRWG.

GENERAL DYNAMICS
CONVAIR DIVISION
SAN DIEGO, CALIFORNIA

SIZE A	CODE IDENT 14170	DRAWING NO. Figure 4.1.6.1 DETECTOR SPEC. DRWG.
SCALE FULL	RELEASED	SHEET

DOC DISTR FORM

REVISION LETTER

PACKAGE NO

The detector installation on the detector cryocooler cold finger is shown on 596-722-016 and is described in Section 4.2.9.

The detector was examined carefully both for geometrical and electrical conformance to the specification; it met them all.

The following table shows the performance as reported by SBRC and as measured by Convair.

	Convair	SBRC
Flux density, watt/cm^2 (RMS)	0.64×10^{-6}	1.8×10^{-6}
Signal, microvolts (RMS)	170	395
Responsivity(BB), volts/watt	6.6×10^4	-
Responsivity(λm), volts/watt	12.0×10^4	9.9×10^4
Noise, microvolts (RMS)	0.8	0.44
NEP(BB), watts	12.0×10^{-12}	7.9×10^{-12}
D*(500°K,f) cmHz$^{\frac{1}{2}}$/watt	5.3×10^9	8.0×10^9
Frequency f, Hz	630	1800
D*(λm,f) cmHz$^{\frac{1}{2}}$/watt	0.95×10^{10}	1.45×10^{10}
Voltage across det.&load volts	23.	20
Load resistor	10K	10K
Detector resistance	12.8K	12.6K
Detector current, ma	1.01	0.885

Thermal noise of a 10K precision 1% resistor (with the 10K load resistor) measured 30×10^{-9} volts (RMS); this corresponds to a calculated thermal noise of 22×10^{-9} volts plus preamplifier noise of 20×10^{-9} volts (calc. N.F. ~ 2.7 db) for a total of 30×10^{-9} volts (RMS). The manufacturer specifies N.F. ~ 4 db at a 5K source resistance for 300-600 Hz.

Time and money did not permit detector uniformity tests to be made. However, from the volumetric nature of the absorption it is estimated that the responsivity is uniform within 10% or less.

A noise test of the preamplifier was made with a 10K 10% precision resistor at the preamplifier input in place of the detector. The preamplifier gain was 1000. The noise at the preamplifier output as measured by a Hewlett Packard 302 A waveanalyzer ($f = 630$ Hz; $\Delta f = 6$ Hz) varied from at least 15 µV to occasional peaks of 60 µV with the average being about 25 to 30 µV. (No output integrator was used on the waveanalyzer.)

Taking the thermal noise for the 5K source impedance (10K resistor in parallel with the 10K bias resistor) equal to $\sqrt{4KTR\Delta f} = (4(1.38\times10^{-23}\,J/^{\circ}C)(300)(5K)(6))^{\frac{1}{2}}$ = 22 nV rms and the equivalent input noise of (30 µV/1000) = 30 nV rms,

$$N.F. = 20 \log\left[\frac{(V_{amp}^{2} + V_{t}^{2})^{\frac{1}{2}}}{V_{t}} = \frac{30}{22} = 1.36\right] = 20(.135) = 2.7 \text{ db} \sim 3 \text{ db} \quad .$$

The amplifier input noise is about 20 nV rms in the 6 Hz bandwidth or about 8 nV rms/$\sqrt{Hz}$ = 0.008 µV rms/$\sqrt{Hz}$ which is small compared to the detector noise (see below).

With the cooled detector (window covered with aluminum foil) attached to the preamplifier input, the noise at the preamplifier output was at least 1.5 mV to occasional peaks of 4 mV with the average being about 2 mV as indicated on the waveanalyzer. The noise at the detector was therefore about (2.0/1000 ~ 2 µV rms) in a 6 Hz bandwidth or about 0.8 µV rms/$\sqrt{Hz}$. A later test with an integrator on the waveanalyzer output gave the same result. SBRC report a noise of 0.44 µV rms for a 1 Hz bandwidth. The difference may be in the cooler since SBRC used liquid He cooling.

The detector noise was also recorded on the analog recorder of the ROSE system ($G = 1000 \times 1 \times 100$ and $Q = 10$; $\tau = 0.01$ sec). A noise of about 4 divisions peak to peak was observed at 0.5 V/div = 2 volts peak to peak or 20 µV pp at the detector. For a bandwidth of $(\frac{1}{4\tau} =)$ 25 Hz this corresponds to about 4 µV pp/$\sqrt{Hz}$ and with a (peak to peak/rms) factor of about 5 gives 0.8 µV rms/$\sqrt{Hz}$. A record at $\tau = 0.1$ gave a peak to peak noise of about 1.5 div as expected.

A 500°K blackbody was set up 113 ± 1 cm from the detector to the aperture plane of the blackbody. A chopper (blade width ~ 0.41") was placed between the blackbody and the detector. The detector was connected to the preamplifier (G_p = 1000) and its output was read on the waveanalyzer ($f \sim 630$ Hz). With a 0.2 inch (= 0.508 cm) diameter aperture the voltage was 172 mV on the waveanalyzer which is equivalent to 172 μV at the detector. The ROSE system was also used to measure the voltage (G = 1000 × 1 × 50) and read 8.4 volts which corresponds to 168 μV at the detector. Checks of the voltages obtained with 0.4 and 0.1 inch diameter apertures agreed within about 5% of those expected on the basis of the nominal aperture area. Checks at preamplifier gains of 100, 200, 500 and 1000 agreed with those expected from the gain change within about 1%.

An average value of 170 μV was used to calculate the detector performance.

With a modulation factor of 0.590, the ratio of the rms fundamental flux to peak to peak flux is $0.590/\sqrt{2} = 0.417$.

$$P = [N(500)-N(300)][(.508^2)\ \frac{\pi}{4}\ /(113)^2](.417)$$

$$= (0.113-0.015)(1.58 \times 10^{-5})(.417) = 0.64 \times 10^{-6} \text{ watt rms/cm}^2$$

The blackbody responsivity is

$$R_{BB} = \frac{170 \times 10^{-6}}{(0.64 \times 10^{-6})(.004)} = 6.65 \times 10^4 \text{ volts/watt}$$

The responsivity at the peak is 1.8 times the blackbody responsivity according to SBRC.

$$R_{\lambda_m} = 6.65 \times 0^4(1.8) = 1.2 \times 10^5 \text{ volts/watt} \quad .$$

The blackbody $NEP_{BB} = \dfrac{0.8 \times 10^{-6}}{6.65 \times 104} = 1.2 \times 10^{-11}$ watt for a 1 Hz bandwidth.

The blackbody $D^*(500K, 630\text{ Hz}) = \dfrac{\sqrt{A\Delta f}}{NEP_{BB}} = \dfrac{\sqrt{.004}}{1.2 \times 10^{11}} = 5.3 \times 10^9 \text{ cmHz}^{\frac{1}{2}}/\text{watt}$

and the peak $D^*(\lambda_m, 630\text{ Hz}) = 1.8(5.3 \times 10^9) = 9.5 \times 10^9 \text{ cmHz}^{\frac{1}{2}}/\text{watt}$.

Measurements were also made of the detector response at various angles of incidence by rotation of the detector-dewar assembly about axis in the plane of the detector perpendicular to the length and width of the detector. The results are shown on Figure 4.1.6.2. Since it was quite difficult to position the dewar assembly precisely, the angles given are probably no more precise than ± 5 degrees or so.

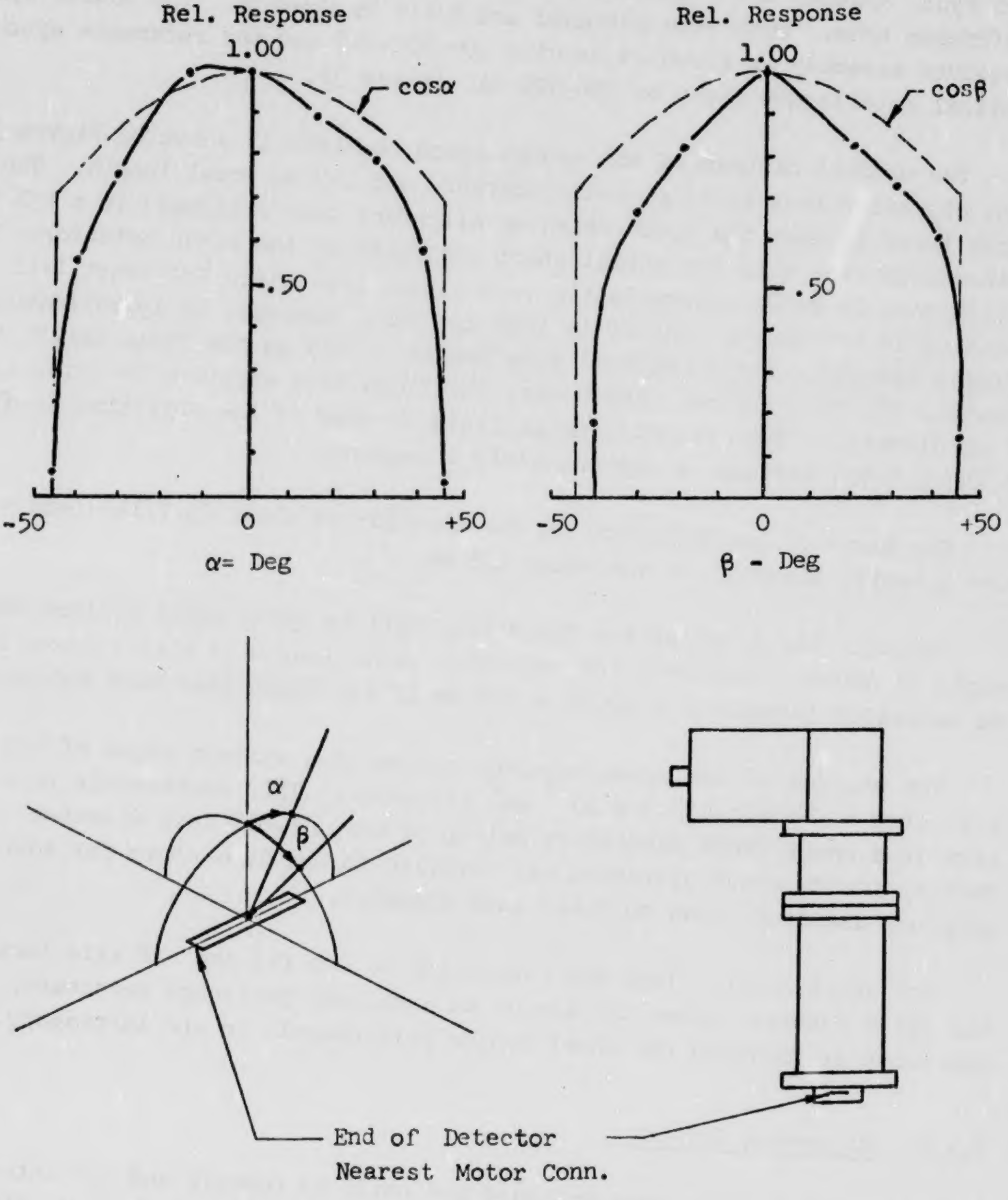


Figure 4.1.6.2 Detector Off-Axis Response

4.1.7 Synch Systems

Two synch systems are required: one for the source beam and one for the reference beam. Both were designed and built by Convair. The source synch receiver assembly is shown on drawing 596-722-017 and the reference synch optical details are shown on 596-722-010 (Sheet 3).

The optical diagram of the source synch receiver is shown on Figure 3.4.7.1. The objective lens is 45 mm clear aperture and 147 mm focal length. The field lens (used to make the synch receiver alignment less critical) is a 43X 0.65 NA microscope lens with the normal short conjugate at the synch detector. The field lens is shown schematically as a simple lens since the exact lens configuration is not known. The field lens aperture, however, is approximately 2 NA (focal length). For an optical tube length of 160 mm the focal length is approximately $160/43 \sim 3.7$ mm. Therefore, the field lens aperture is about $1.3\ (3.7) \sim 5$ mm diameter. The resulting total field of view of the objective is about $5/147 = 0.034$ radians or approximately 2 degrees.

The image of the objective on the detector is about $(3.7/147)(45) \sim 1.1$ mm, the detector diameter is nominally 1.5 mm.

Normally the image on the field lens will be quite small so that misalignments of about ± 2 mm over the objective focal length in either direction can be tolerated (compared to about ± 0.5 mm if the field lens were not used).

The etendue of the synch receiver system at a maximum range of 4.0 km is estimated to be about 2.3×10^{-7} cm^2 steradian. This corresponds to a source size in a short range laboratory set-up of about 0.017 inch diameter. Satisfactory source synch operation was verified in the laboratory for source aperture diameters down to 0.010 inch diameter.

For short ranges (less than about 150 to 200 ft) the off axis location of the synch receiver makes the use of an auxiliary periscope necessary. Such a periscope is provided for short ranges particularly in the laboratory.

4.1.8 Alignment Systems

The alignment devices were designed and built by Convair and are intended for use in aligning the source and receiver stand assemblies. Details of the alignment devices are shown on drawing 596-722-014.

There is a wide-field and a microscope alignment device for use at each stand assembly. The devices for use with the source stand assembly (which attach to the source blackbody) are not interchangeable with those for use with the receiver stand assembly. The latter slide into the clip at the monochromator entrance slit.

A reticle is incorporated in each wide-field alignment device. A central cross 10 mm long is divided into 0.5 mm intervals. The center is the aiming point for coarse stand alignment. The short lines of the scale are 0.3 mm or 300 microns long and the long lines are 0.7 mm or 700 microns long corresponding to the two slit widths required for the specified spectral resolution of 0.01 micron for the 101 line/mm and 240 line/mm gratings, respectively. It is intended that these may be used for estimation of the field view in the emission mode of operation. The remainder of the reticle field is covered with a grid the lines of which are spaced 1.0 mm apart. These may be used for range estimation to objects of known size or size estimation of objects at known range.

The microscope alignment device contains a cross hair the center of which is the aiming point for precise stand alignment.

For further details of alignment device use see the System Operation Section 5.0.

4.2 Mechanical Components

In this section detailed descriptions are given of components which are primarily mechanical as well as the mechanical features of other components.

The components which are primarily mechanical are the stands, the auxiliary stands and the electronic enclosures. These are combined along with other equipment into a source assembly and a receiver assembly as shown in Figure 4.2.1 and general assembly drawing 596-722-003.

The other components whose mechanical features are described here are for the most part components which primarily serve an optical function.

The approximate size and weights of the major assemblies shown on Figure 4.2.1 are as follows:

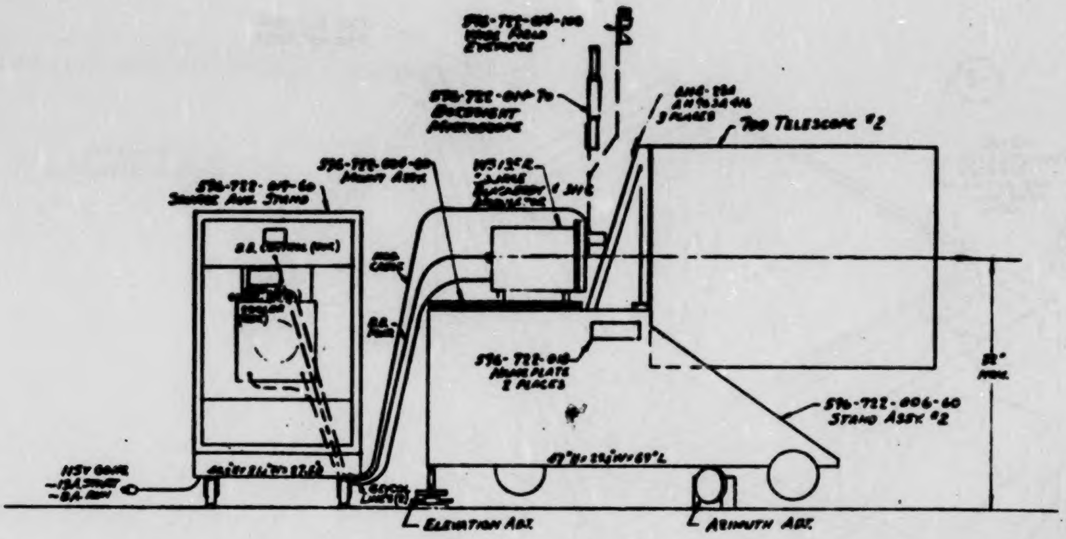
Item	L	W	H	Wt. (est.)
Receiver Stand Assembly	69"	29.5"	48.5"	400
Receiver Aux. Stand Assy.	27.5	26.1	50	270
Electronic Console (DVM)	26	22.3	53.8	370
Electronic Console	25	22.3	53.8	370
Source Stand Assy.	69	29.5	47	300
Source Aux. Stand Assy.	27.5	21.1	40	210

4.2.1 Stands

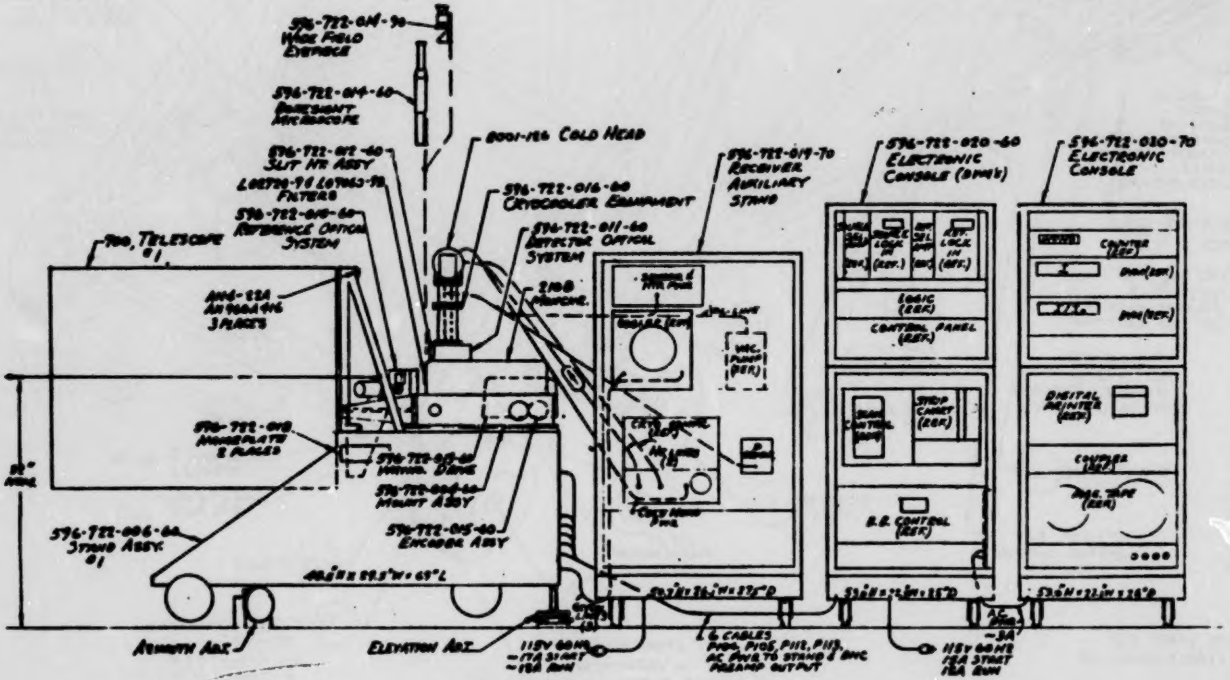
The stands were designed and built by Convair and serve as the major supporting structure for the other components. There are two stands: a source stand and a receiver stamd. They are nominally identical except for some additions to the receiver stand. The basic framework is shown in Figure 4.2.1.1 and, in more detail, on drawing 596-722-005. The framework material is aluminum to minimize thermal alignment variations.

Electrical power to the receiver stand is normally supplied from the electronic consoles but may be supplied from an independent source if desired. The only unit in the stand supplied directly from the 110V 60 Hz stand line input is the mercury lamp and amounts to only about 0.2 amp. Of course, any equipment plugged into the convenience outlets would add to this load.

The extruded tubular framework elements are one inch square (outside) with a one-eighth inch wall thickness and are joined together by welding. After welding and stress relieving the assembly critical areas at the locations of the telescope pads and the mounting holes for the monochromator (receiver) or blackbody (source) were carefully machined. Finally, equipment and trim


596-722-018-100 Wide Field Eyepiece
596-722-014-70 Boresight Microscope
AN6-224 AN960A416 3 Places
700 Telescope #2
596-722-006-60 Mount Assy
596-722-019-60 Source Aux. Stand
B.B. Control
Pwr. Cable
B.B. Pwr.
596-722-018 Hinge Plate 2 Places
596-722-006-60 Stand Assy #2
52" Min.
115V 60Hz —13A Start —8A Run
Elevation Adj.
Azimuth Adj.

-70 Source Assy.


596-722-014-70 Wide Field Eyepiece
596-722-014-60 Boresight Microscope
8001-126 Cold Head
596-722-012-60 Slit Hr Assy
Filters
596-722-010-60 Reference Optical System
596-722-016-60 Cryocooler Equipment
596-722-011-60 Detector Optical System
700, Telescope #1
AN6-224 AN960A416 3 Places
596-722-019-70 Receiver Auxiliary Stand
596-722-020-60 Electronic Console
596-722-020-70 Electronic Console
Logic (Ref.)
Control Panel (Ref.)
Strip Chart (Ref.)
B.B. Control (Ref.)
Counter (Ref.)
Digital Printer (Ref.)
Coupler (Ref.)
Mag. Tape (Ref.)
Vac. Pump (Ref.)
596-722-018 Hinge Plate 2 Places
596-722-013-60 Manual Drive
596-722-006-60 Mount Assy
596-722-015-60 Encoder Assy
596-722-006-60 Stand Assy. #1
52" Min.
Azimuth Adj.
Elevation Adj.
115V 60Hz —17A Start —12A Run
6 Cables P100, P105, P112, P113, AC Pwr. to Stand & BNC Preamp Output
115V 60Hz 15A Start 15A Run

-60 Receiver Assy.

Figure 4.2.1 Source and Receiver Assemblies

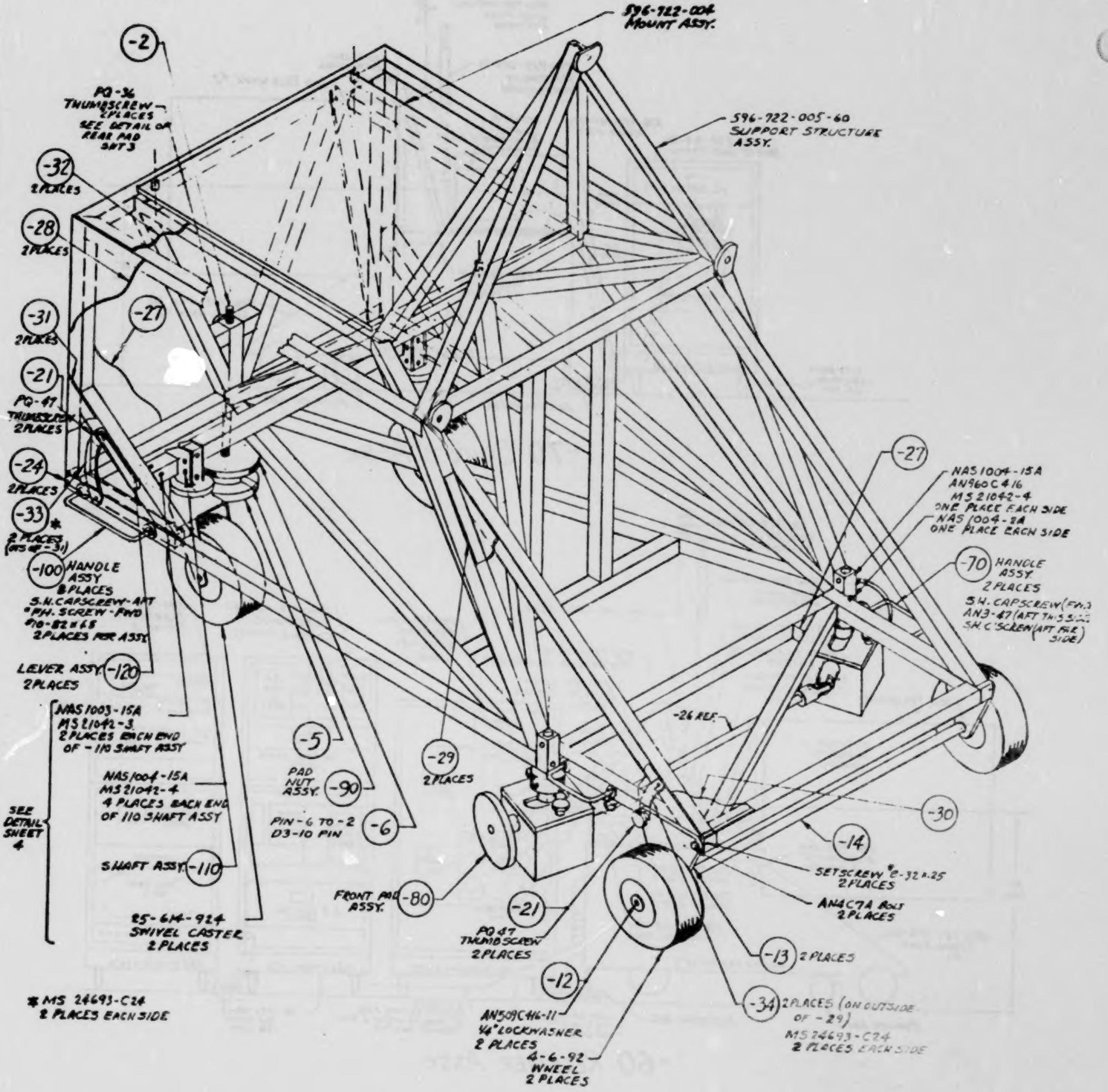


Figure 4.2.1.1 Stand Assembly

panels were installed as shown on drawing 596-722-006. The stands are painted EN-2GO gold to match the electronic consoles. Telescope number one is mounted on stand number one and is used for the receiver assembly. Telescope number two is mounted on stand number two and is used for the source assembly. All trim panels are marked on the inside surface for identification (telescopes are marked on the rear surface of each primary mirror).

The major load on each stand is the telescope which is attached to the stand at three pad locations. Taper pins are used at each pad to ensure that alignment will be preserved throughout disassembly and reassembly of the telescope on the stand. It can be observed from the arrangement of the framework members in Figure 4.2.1.1 that the loads are carried directly to three pads upon which each stand rests.

Most of the telescope weight is carried directly down to the support pads by frame members in compression. Since the telescope center of gravity is forward of the front pads there is an overturning moment which is carried as a couple by the upper frame members; the resulting loads are again carried directly by tension or compression to the support pads. The static deflection of the front of the telescope is about 0.005 inches. Every effort has been made to utilize tension or compression members and to avoid bending members so as to reduce structural deflections.

The other major component mounted on the stand is located near the telescope focus: the monochromator on the receiver stand and the source blackbody on the source stand. These two components are each mounted in a similar manner by means of the mounting plates; see drawing 596-722-004. The entire mounting plate is attached to the stand by means of three screws each of which allow vertical adjustment. Common rotation of these screws results in vertical translation of the mounting plate while differential rotation results in rotation of the plate about horizontal axes. Cap nuts on top allow the screws to be locked after adjustments are made.

Lateral positioning or rotation about a vertical axis of the component mounted is accomplished by three screws which act against spring loaded plungers. Before adjustments are made three bolts which lock the component to the mounting plate should be loosened (tighten after adjustment). Access to these bolts is obtained by removal of one side panel of the stand.

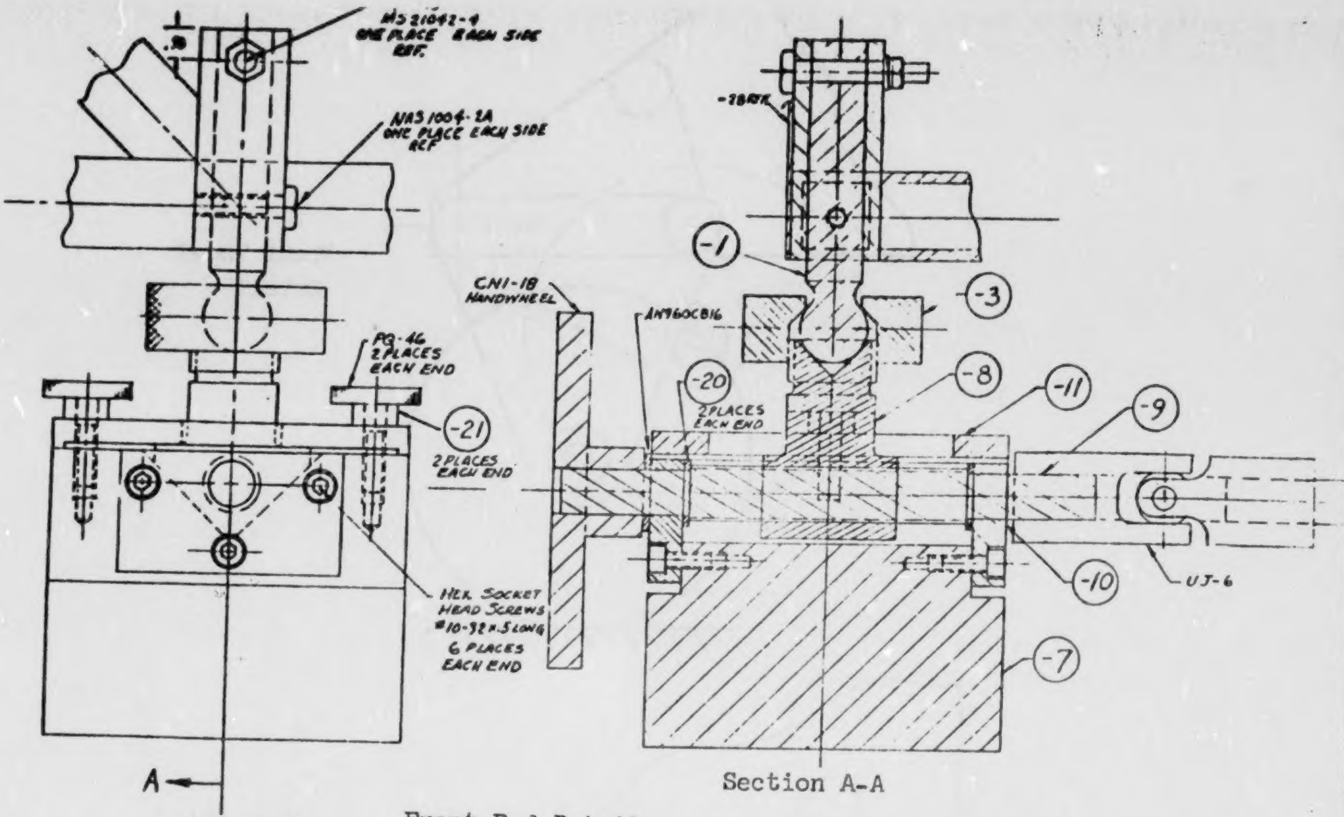
Note that these mount adjustments move all of the components relative to the each telescope. For the source system only the source blackbody is moved. For the receiver system the monochromator along with the reference optical system and detector optical system attached to it are moved as a unit. Thus, the relative alignment of these latter components is not disturbed by repositioning of the whole unit relative to the telescope focus (except the sphere of the reference optical system must be readjusted since the reference blackbody position is fixed).

The stand assembly may be conveniently adjusted in azimuth and elevation. The stand was designed to pivot about the vertical axis of the rear pad each front pad being a radial distance of 40.35 inches from the rear pad. Coarse azimuth adjustment is made by moving the stand as a whole and fine adjustment in azimuth over a range of about ±1° is made by means of control knobs on the front pads (connected by means of a tie rod) which turn a screw mechanism; see Figure 4.2.1.2. Turning the knob on either pad turns a 64 threads per inch screw which causes the stand to rotate about $0.0156/40.35 \sim 0.000387$ radians per turn or 0.022 deg per turn. At the longest range of 4 km this corresponds to about 1.5 meters/turn so that the telescope diameter of approximately 0.6 meter corresponds to about 0.4 turn. The corresponding image motion at the telescope focus (normal to the slit length) is about 1.2 mm per turn. Knob motion for the image diameter of about 0.93 mm (corresponding to 2 telescope diameters at 4 km) is about 0.8 turn. Although a finer screw would give more precise pointing of the system it was decided that this was the finest practicable screw that should be used. At shorter ranges the linear range of adjustment is correspondingly less being about 0.15 meter/turn at 0.4 km; therefore, a motion equal to the telescope diameter at 0.4 km corresponds at about 4 turns of the azimuth control knob. Note that this control has backlash which must be considered in making azimuth adjustments.

Elevation adjustments over a range of about ±5 degrees are made by means of a screw on the rear pad; see Figure 4.2.1.2. Adjustments in elevation cause the telescope image to move along the length of the entrance slit and are less critical than the azimuth adjustments. Consequently, a coarser screw pitch of 18 threads per inch is used. The distance between the rear pad and a line connecting the front pads is 38.8 inches. The elevation rate is, therefore, $(0.0555/38.8) = 0.00143$ radians per turn or 0.082 degrees per turn. For angles exceeding the range of adjustment blocks may be placed beneath the pads although this will usually not be as rigid as is normally obtained. An elevation mirror being built on a follow-on contract will greatly facilitate paths which deviate substantially from a horizontal plane.

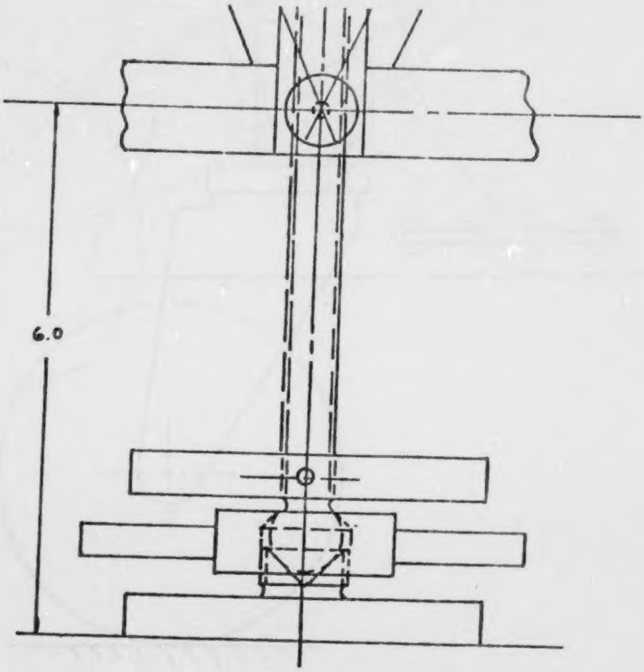
In order to conveniently transport the stand assemblies, retractable wheels can be lowered and the assembly rolled into place. The front wheel mounts are fixed and the rear wheel mounts swivel. The wheels have zero-pressure pneumatic tires to cushion shock loads during transport.

The front wheels are connected to triangular plates on each side of the stand. A screw through each plate may be placed in either of two holes in the frame to lock the plate in either the upper or lower position; see Figure 4.2.1.3. The rear wheel mounts are connected to a shaft the position of which is controlled by an arm on each side of the stand frame. A screw through each arm may be placed in either of two holes in the frame to lock the arm in either the upper or lower position corresponding to the wheels down or wheels up position, respectively; see Figure 4.2.1.3. Note that the screw should be placed in the



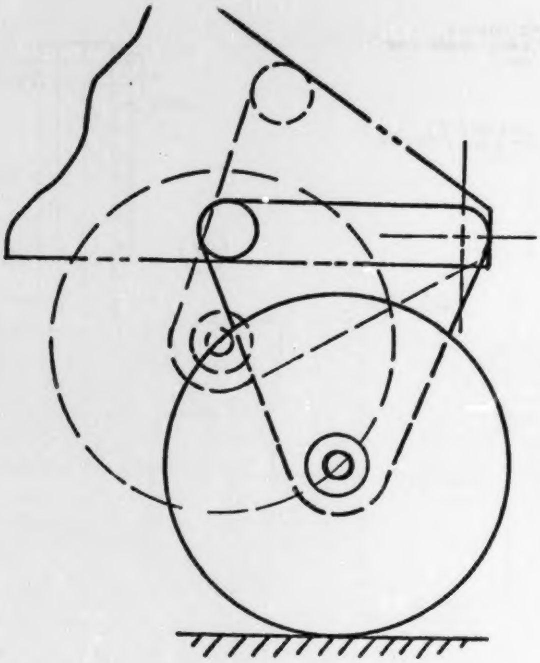
Section A-A

Front Pad Detail

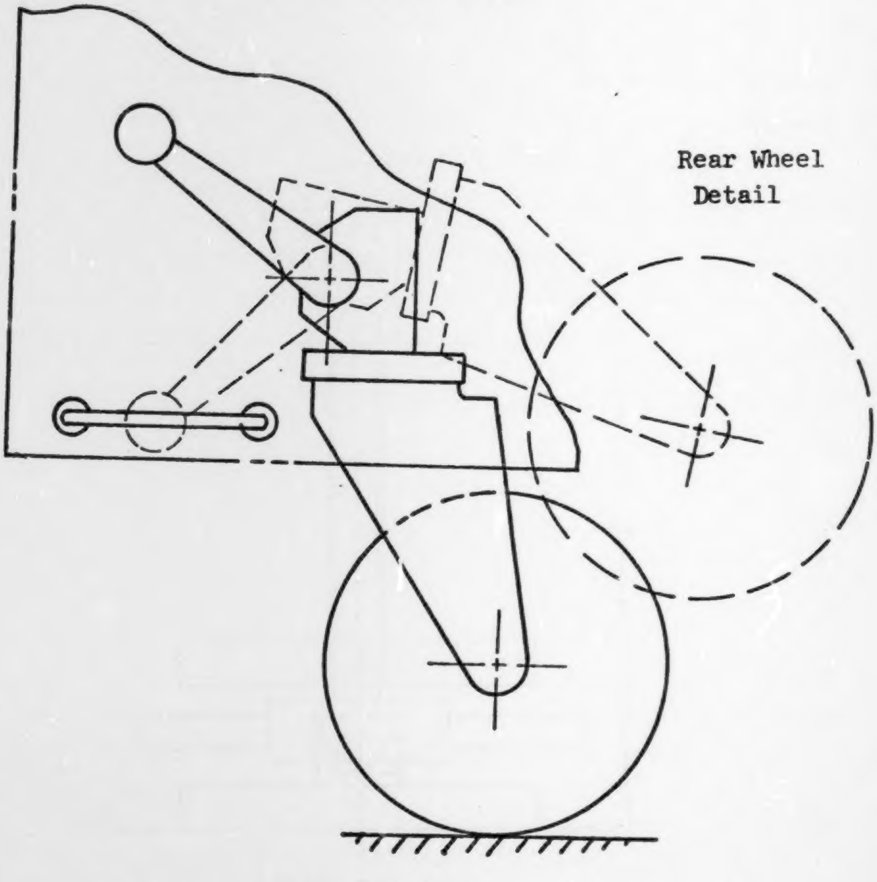


Rear Pad Detail

Figure 4.2.1.2 Stand Pad Details



Front Wheel
Detail



Rear Wheel
Detail

Figure 4.2.1.3 Stand Wheel Details

hole in the arm before it is put into the lower position because of the close proximity of the lifting handle.

Lifting handles are provided to assist in controlling the stand during transport and may be used during raising or lowering of the wheels. It will be found convenient, however, in the latter case to use a laboratory jack near the center of the frame. At the rear of the stand be sure the jack clears the rear pad completely. At the front of the stand be sure the jack does not interfere with the axle in the lower position.

The various electrical and coolant lines are grouped for convience at the panel on the rear of the receiver stand. All of the connections are clearly labelled; see Figure 4.2.1.4. Convenience outlets for 110 volts 60 Hz power are provided. Note that the plugs and jacks on the stand interface are different from one another so that it is impossible to place a plug into the wrong jack.

The reference blckbody is attached to a framework on the receiver stand by four bolts. The blackbody may be removed either by removing these four bolts or by removing the framework and blackbody as a unit. Access for blackbody removal is obtained by removing the side panels.

Access to the synch receiver preamplifier and the mercury lamp power supply is obtained by removing the right side panel.

System nameplates are attached to each side panel of each stand; see drawing 596-722-018.

4.2.2 Auxiliary Stands

Because of the necessity of removing vibrating equipment from the main stands it was decided to place some of the equipment (particularly that which vibrates) in auxiliary stands. There is a source auxiliary stand and a receiver auxiliary stand as shown in Figure 4.2.1 and on drawing 596-722-019. The enclosures for the auxiliary stands are Emcor II units from Ingersoll Products, Chicago, Ill. and are painted EN-2G0 gold color.

Power lines and coolant tubing are routed down along the inside of each auxiliary stand and extend from the bottom of the stand. A plate is used to keep these lines clear of the drawer.

Equipment is secured to the shelves in the auxiliary stands by means of one or more thumbscrews each which can be easily removed in order to permit changes of equipment.

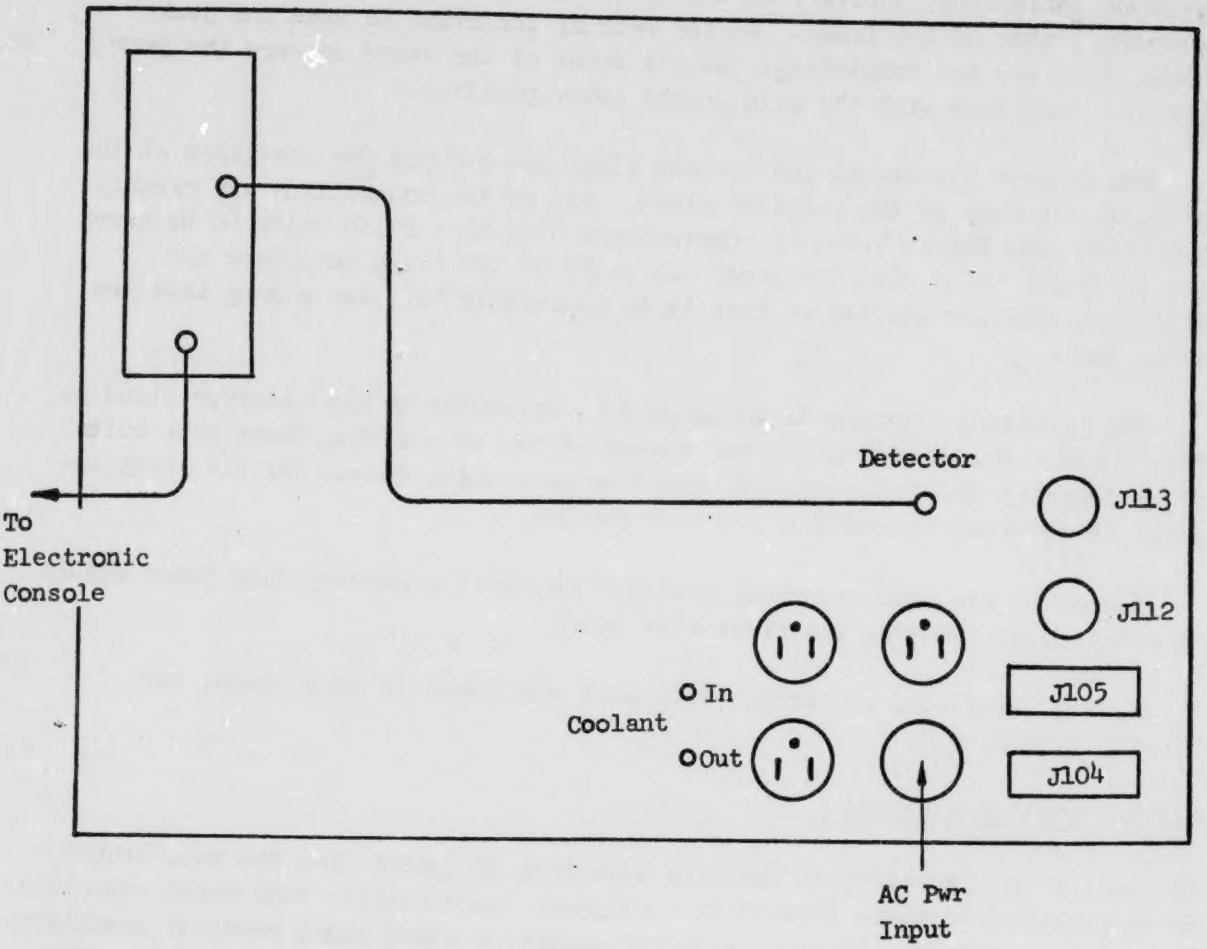


Figure 4.2.1.4 Stand Connection Panel

Electrical power is normally supplied to the auxiliary stands directly and are protected by 15 amp circuit breakers located just inside the rear door of each auxiliary stand. The approximate current measurements are as follows:

	Start	Run
Source Auxiliary Stand	13 amp	8 amp
Receiver Auxiliary Stand	17 amp *	12 amp

* if all equipment started at once; therefore, starting must be staggered because of the 15 amp breaker.

4.2.3 Electronic Consoles

The electronic enclosures for the consoles are Emcor II units from Ingersoll Products, Chicago, Ill. and are painted EN-2GO gold color. Details of the electronic consoles and equipment locations are shown on drawing 596-722-020.

Electrical power is normally supplied to one electronic console and the other console is plugged into the first. Junction strips are located just inside each rear door of each console. The consoles are protected by a 15 amp circuit breaker. The combined 110V 60Hz current drain for both consoles is 15 amp starting and 12 amp running. Since all equipment is not started at once the breaker should carry the starting currents.

Details of electrical interconnections are described in detail in Section 4.3 and are collected for convient reference on drawing 596-722-033.

4.2.4 Blackbody Plumbing and Mounting

The mechanical details of the first of several components, namely the blackbodies, are given in this section. There are two blackbody units: one in the source assembly and one in the receiver assembly. Each consists of three parts: the blackbody housing, a closed cycle cooler and a temperature controller. The interconnections of these three parts is shown on Figure 4.2.4.1. (note: fan in blackbody apparently deleted by manufacturer) The closed cycle cooling loop is completed by two 3/8 inch diameter Polyflo plastic lines. Care should be exercised in connecting the output of the cooler to the input of the blackbody housing and vice versa. The electrical connection for the source blackbody is made directly from the temperature controller to the blackbody housing (as supplied by the manufacturer). No jack and plug numbers were assigned to this simple connection for the source blackbody (the pin designations used are identical to that of the receiver blackbody). The receiver blackbody connections were run through the interface panel on the rear of the receiver stand for convenience. The connectors used there are identical to those on the blackbody units as shown on Figure 4.2.4.1. Therefore, the temperature

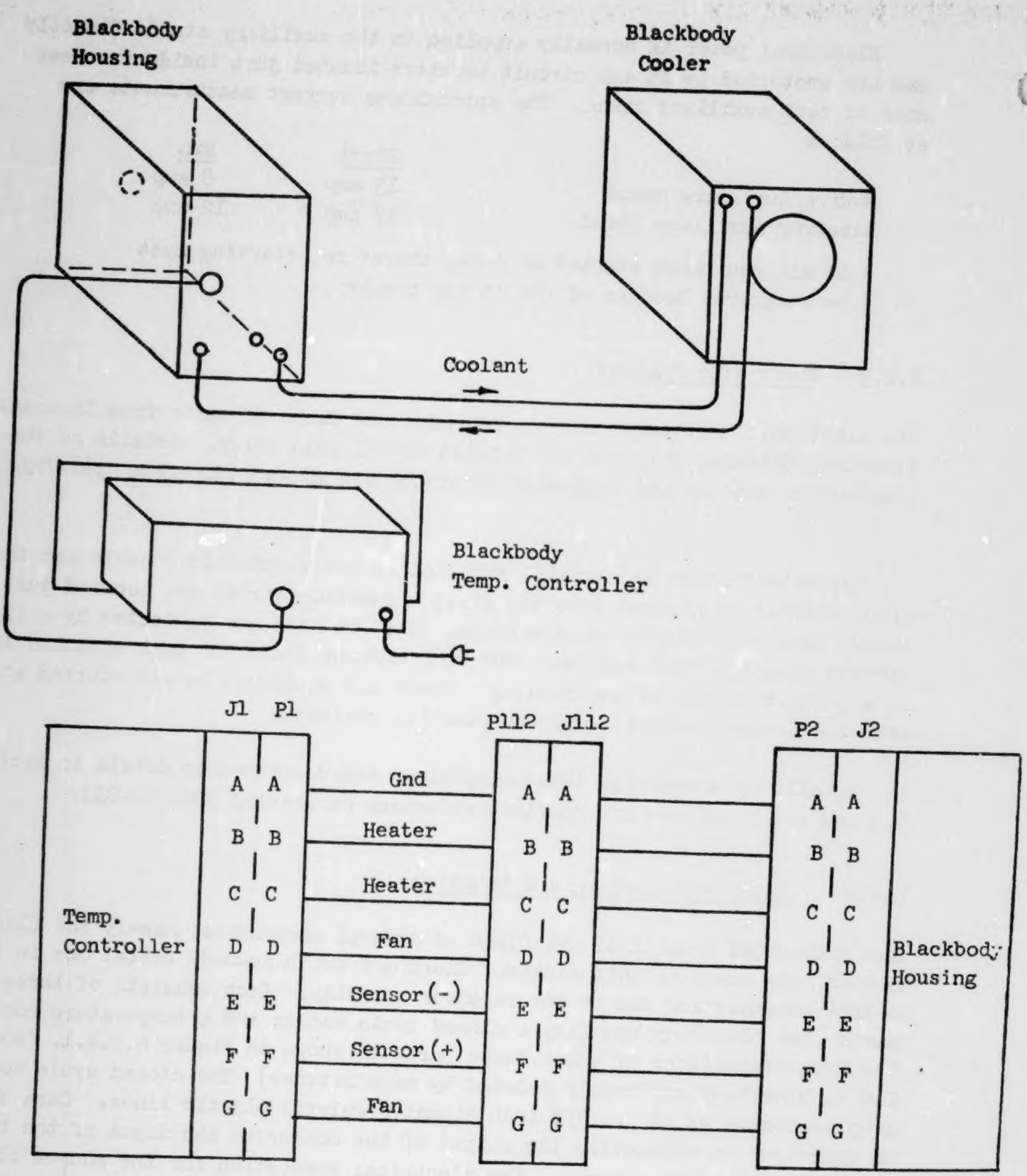


Figure 4.2.4.1 Blackbody Interconnections

controller can be directly connected to the blackbody housing if desired (for bench testing, for example).

The blackbody housing drawing supplied by the manufacturer contains errors and Figure 4.2.4.2 is provided to show the blackbody housing geometry. The internal plumbing of the blackbody housing is also shown on Figure 4.2.4.2. It should be noted that the blackbody plumbing supplied by the manufacturer was partly made up of plastic tubing. Power failure would stop the coolant flow and heat from the cavity would melt the plastic tubing inside the blackbody housing requiring a tedious repair and cleanup. Therefore, the plastic tubing was replaced by copper tubing after obtaining permission from the manufacturer. Because the coolant fittings could not be removed from the cavity itself it was necessary to make up a hybrid connector at the cavity. The half of this connector nearest the cavity is half of the original connector and the other half is half of a Swagelok connection. The two halves are silver soldered together.

It was stated by the manufacturer that the plastic tubing on the outside of the blackbody housing should not melt even with a power failure. However, running the cooler for one hour after turning off the electrical power is still recommended.

Start up and shut down of the blackbodies are described in the operation section.

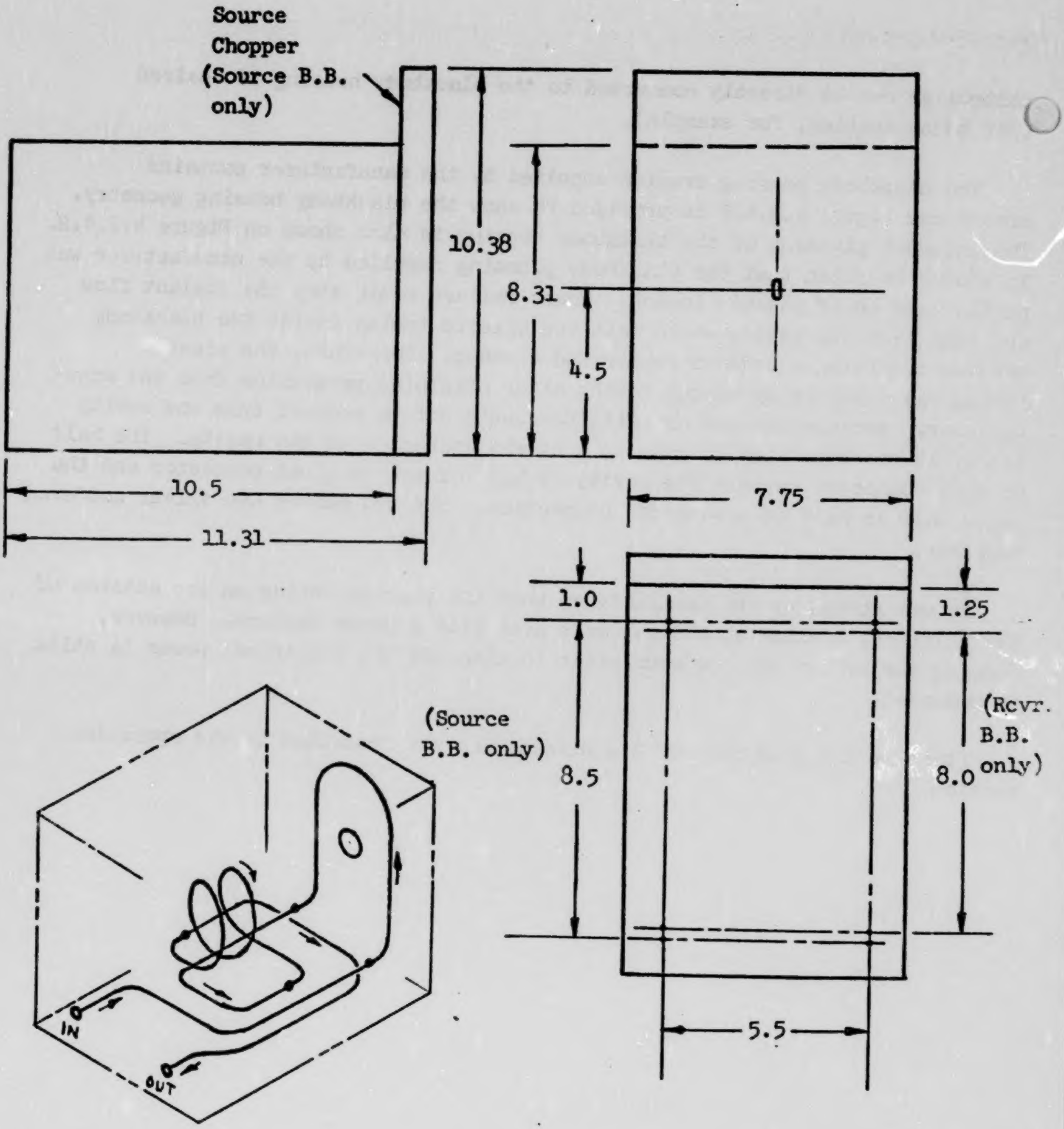


Figure 4.2.4.2 Blackbody Geometry & Plumbing

4.2.5 Telescopes

Although the telescopes are primarily considered optical elements there are a number of mechanical details which should be discussed. See Figure 4.2.5.1.

The basic structural elements of the telescope are the primary and secondary cell rings connected by a thin but stiff shell. The primary cell ring not only supports the primary mirror but also serves to distribute the loads to the telescope mounting pads. The primary mirror is supported laterally by means of three tie rods each of which pass through a radial hole in the primary mirror substrate. The tilt of the primary mirror and its axial position are each controlled by three screws at the back of the primary mirror. The primary mirror is spring loaded against these adjusting screws at each screw location.

The secondary mirror is provided with lateral and tilt adjustments which are incorporated in the secondary mirror cell supported by thin vanes.

The telescope is supported at three locations on the rear face of the primary cell ring. Taper pins at these locations ensure precise maintenance of alignment. Bolts used to attach the telescope to the stand pass through the stand pads and are screwed into tapped holes in the telescope ring. Care should be taken not to overtighten these bolts thus stripping the threads in the ring.

In assembling the telescope onto the stand it is assumed that one person will support each handle of the telescope and bring it close to the stand aligning the taper pins and holes. Slide the telescope onto the taper pins carefully so as not to bend them; as quickly as possible insert the bolt in the top pad and tighten it finger tight. At this point the weight of the telescope is supported and the two bottom bolts may be inserted in a more leisurely manner. Reverse the procedure for removal of the telescope. Again use care in removing the telescope not to bend the taper pins. If the telescope sticks to the stand a little prying and/or tapping will loosen it. If the taper pins should get bent straighten them or if necessary they can be replaced.

4.2.6 Reference Optical System

Mechanical details of the reference optical system are described in this section and are shown on drawing 596-722-010. The reference optical system consists of the reference blackbody, a spherical mirror, a flat mirror an intermediate focus assembly, a toroidal mirror, the reference chopper and supporting structure.

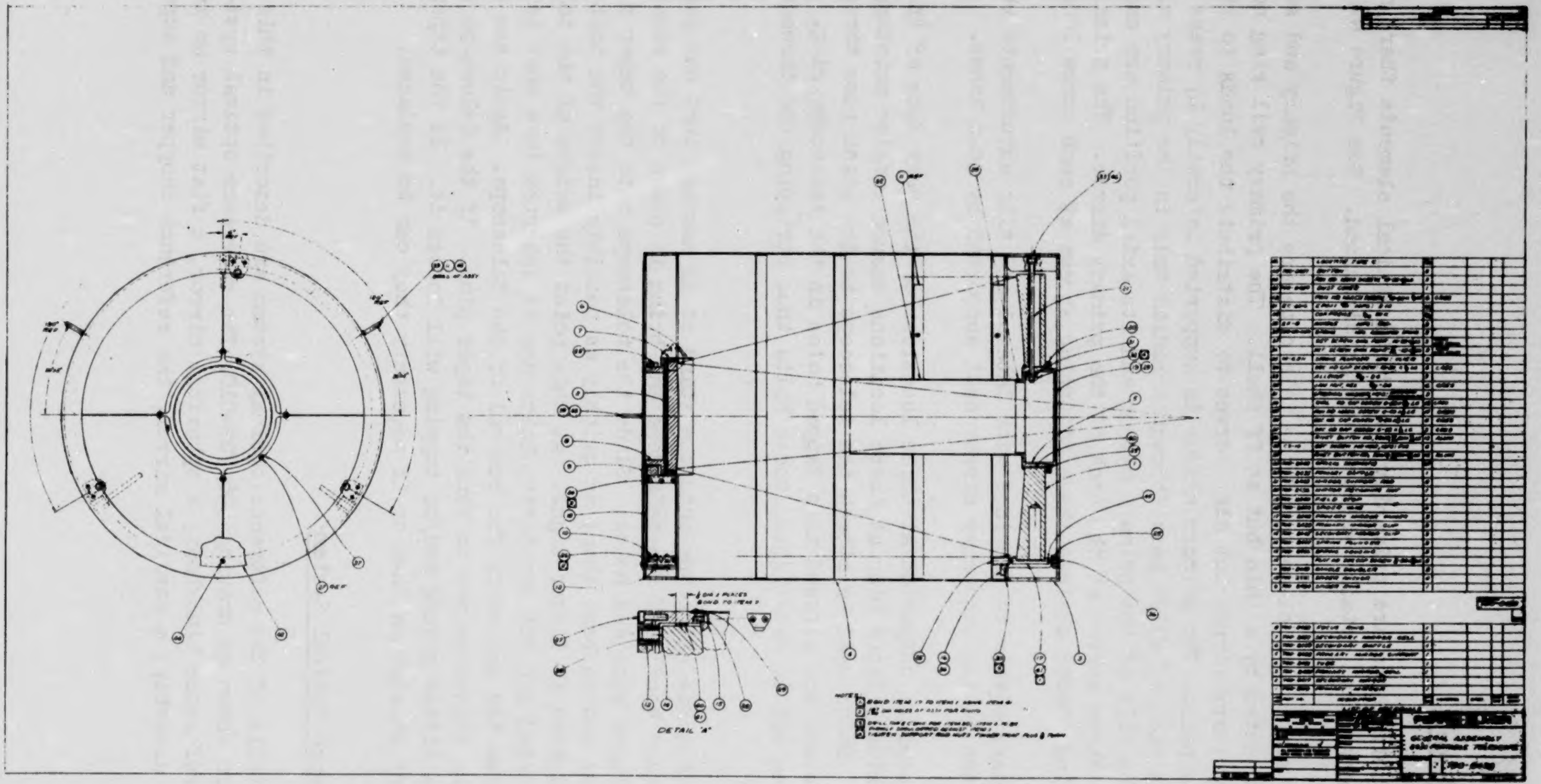


Figure 4.2.5.1 Telescope General Assembly

4-50

The reference optical system (except for the toroidal mirror and the reference blackbody) is mounted on the front of the monochromator; taper pins ensure maintenance of alighment. The toroidal mirror is mounted on the side of the case of the detector optical system which is also attached to the monochromator by means of taper pins. Thus alignment of the toroid relative to the rest of the reference optical system is preserved even if components are removed and replaced. The reference blackbody was judged to be too heavy to support on the monochromator; consequently it is mounted in a fixed position on the stand. After adjustment of the monochromator-reference optics-detector optics assembly position it is necessary to slightly readjust the spherical mirror of the reference optical system.

In order to provide access to the reference blackbody for the radiation probe it is necessary to remove the spherical mirror which is therefore kinematically mounted. Holding down the spherical mirror mount assembly to keep it from tipping, the three hold-down springs are released which permits removal of the assembly.

The stem mounted flat diagonal mirror is adjustable for tilt by means of three screws which push against the back of the mirror. The mirror is held against the screws by means of a spring on the stem attached to the mirror.

The stem mounted toroidal mirror mount has axial and three tilt adjustments as well as adjustable rotation about the stem mount axis.

The chopper is mounted on ultra-precision ball bearings (which are preloaded to eliminate axial play) in a housing to protect both the chopper and operating personnel. The housing is mounted on a plate which is pivoted so as to permit small variations of the nominal 45° reflection angle. Three screws, one below the baseplate, lock the chopper housing in position. Clearances between the chopper and reference synch elements within the chopper housing are only about 0.03 inches; therefore, axial positioning of the chopper blade is critical. The outer edge of the collar on the shaft end opposite the motor should be flush with the end of the shaft. Axial pre-load is obtained by pushing the opposite collar and pulling on the shaft with the fingers and locking the collar set screw. Check to ensure the chopper turns freely before energizing the reference chopper motor.

4.2.7 Monochromator

A number of mechanical modifications have been made to the monochromator and its attachment to the stand are described in this section. These modifications include (in addition to the added entrance slit height assembly described in the optical section) addition of a wavenumber shaft encoder and modifications of the wavenumber drive.

The monochromator is attached to the plate of a mount (which is attached to the receiver stand) by means of three bolts which also serve to lock the mount plates together. Figure 4.2.7.1 shows a detail of the connection. Access to the monochromator attachment screws is required for removal of the monochromator or for loosening of the adjustment screws in order to change the monochromator lateral position. Such access is obtained by removal of one of the stand side panels.

A shaft encoder was connected to the shaft which controls the grating position and thus wavenumber in order to provide a direct reading of wavenumber. Drawing 596-722-015 shows the encoder installation underneath the base of the monochromator. The encoder shaft is connected by an antibacklash gear (1 to 1 ratio) to a gear mounted on the wavenumber shaft.

Modifications to the wavenumber drive are shown on drawing 596-722-013 and include the following:

Replace 2 RPM motor with 3 RPM motor.
Stiffen one shaft in the wavenumber drive.
Remove unused marker switches wiring and plug.
Change power plug.
Add a switch to permit driving the wavenumber shaft and
 drum in either direction.
Provide electrical limits on both directions of wavenumber shaft travel.

The motor speed was changed to obtain the scan speed specified.

The unstiffened wavenumber drive shaft was so flexible that it resulted in jerky rotation of the wavenumber shaft at high scan rates. Stiffening this shaft eliminated the jerkiness in the rotation rate.

Since the gear set-up in the wavenumber drive system is not described in the monochromator manual, Figure 4.2.7.2 is included here. A convient scan speed chart is provided on the top of the wavenumber cover and is also shown on Figure 4.2.7.2. Since the gears are not visible with the cover in place, an index pin is provided in the chart to show the gear set-up in use. The

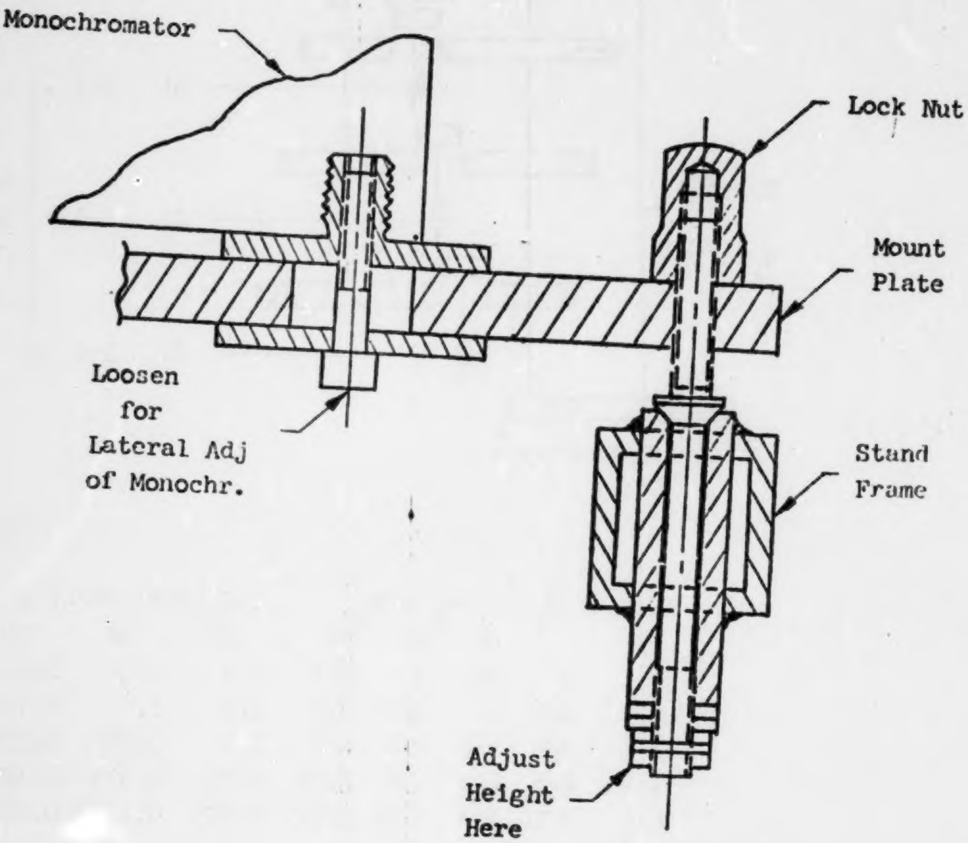
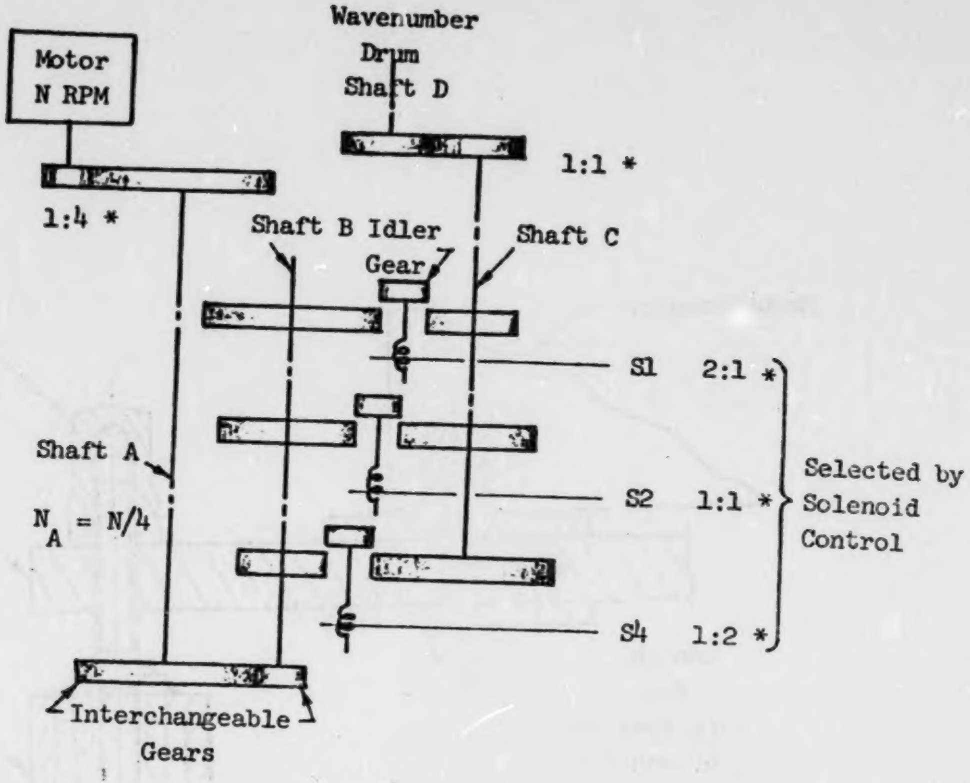


Figure 4.2.7.1 Monochromator Mount Detail



Ratio*	N_B	$N_C = N_D$			N_D (RPM) for N = 3 RPM		
		S1	S2	S4	S1	S2	S4
4:1	N	2N	N	N/2	6.0	3.0	1.5
2:1	N/2	N	N/2	N/4	3.0	1.5	0.75
1:1	N/4	N/2	N/4	N/8	1.5	0.75	0.375
1:2	N/8	N/4	N/8	N/16	0.75	0.375	0.1875
1:4	N/16	N/8	N/16	N/32	0.375	0.1875	0.09375

* Ratio = Driver/Driven

Wavenumber Drive Schematic

Gear Setup			WVNO	DRUM	RPM
Driver	Driven	Ratio	S1	S2	S4
96	24	4:1	6	3	3/2
80	40	2:1	3	3/2	3/4
60	60	1:1	3/2	3/4	3/8
40	80	1:2	3/4	3/8	3/16
24	96	1:4	3/8	3/16	3/32

Wavenumber Drive Chart

Figure 4.2.7.2 Wavenumber Drive Details

chart shows for each of the four available gear set-ups the three scan speeds available for selection by the switch on the monochromator control panels (S1 is the fastest speed, S2 is the medium speed and S4 is the slowest speed).

The switch for changing the direction of wavenumber drive is located on the side of the drive unit. Normally this switch will be in the up position for which the drive will scan up in drum number and wavenumber.

4.2.8 Detector Optical System

The mechanical features of the detector optical system are shown on Figure 4.2.8.1 and drawing 596-722-011. The components are located in a light tight housing which is attached to the monochromator. Taper pins are used to ensure precise positioning.

The toroidal mirror is mounted on the back housing plate and has three adjusting screws for tilt control and a small axial motion of the toroidal mirror.

The flat diagonal mirror is also mounted on the back housing plate and can be rotated in the mount and tilted to provide lateral adjustment of the image on the detector.

The "Cassegrain" assembly is composed of two units: one large main unit is used to support the concave primary mirror (to which is attached the field lens) and the other unit consists of two concentric rings the inner one of which has the small convex secondary mirror attached. Image symmetry is obtained by lateral adjustment of this inner ring relative to the outer ring by means of four pin-ended screws in the side of the outer ring which fit in the groove in the inner ring. The distance between the "Cassegrain" mirrors and their relative tilt is adjusted by means of three spring loaded screws in the top of the outer ring. Dimensions for this "Cassegrain" pre-alignment may be obtained from Figure 4.1.5.1. The "Cassegrain" unit has been pre-aligned and should not require realignment unless some catastrophe occurs.

The "Cassegrain" unit as a whole is adjustable with respect to the housing in the axial direction by means of 3 push-pull sets of screws. The lateral position is retained by the close fitting pull screws.

Lateral adjustment of the detector relative to the "Cassegrain" unit is accomplished by means of three screws in blocks on top of the housing which push against the bottom flange of the dewar which contains the detector. Before making such adjustments it is necessary to loosen the screws which attach the bottom flange of the dewar to the housing enough to allow relative movement but still snug. After lateral adjustment these screws are tightened firmly and the focus of the "Cassegrain" unit is rechecked and changed if necessary.

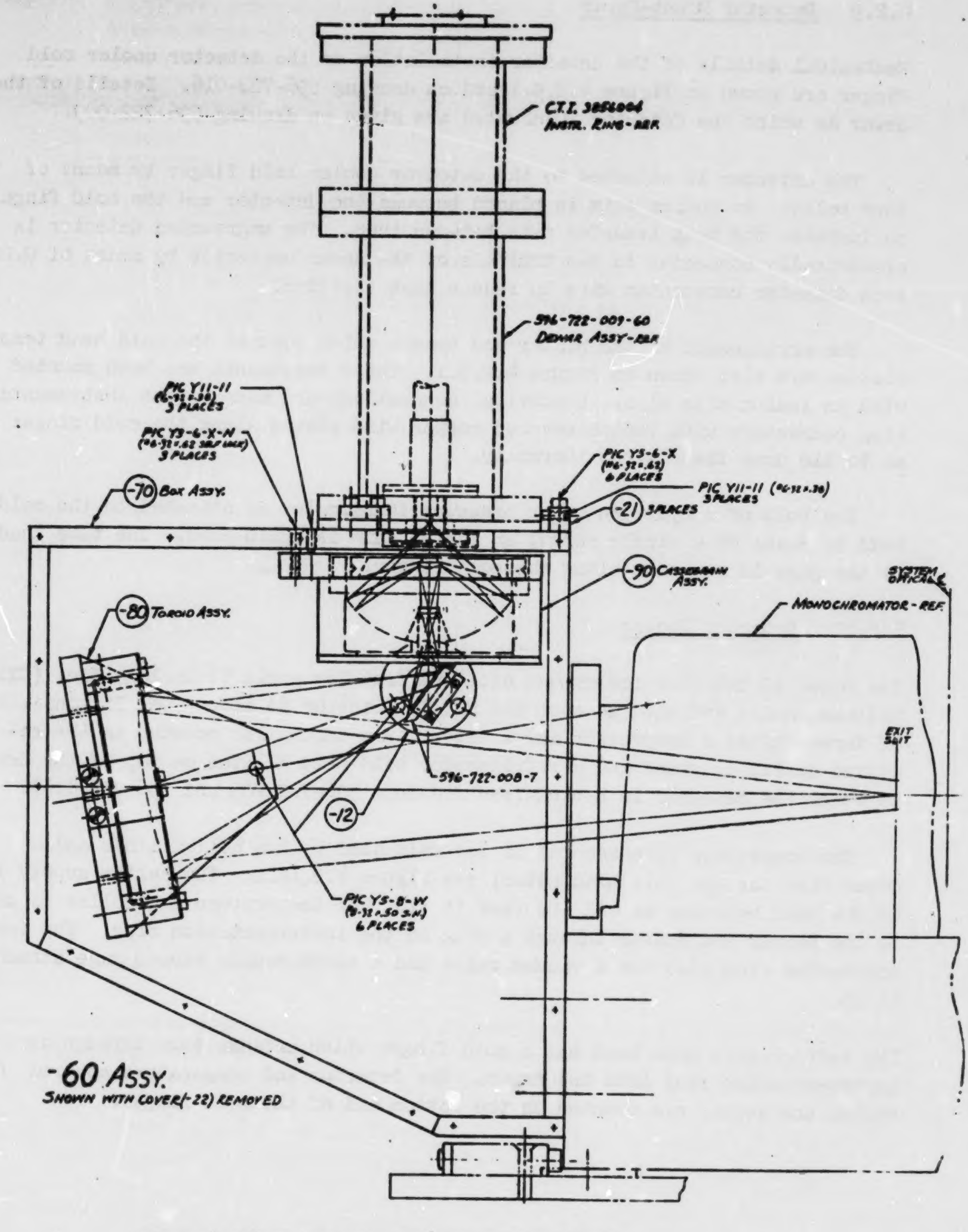


Figure 4.2.8.1 Detector Optical System Details

4.2.9 Detector Mount-Dewar

Mechanical details of the detector installation on the detector cooler cold finger are shown on Figure 4.2.9.1 and on drawing 596-722-016. Details of the dewar in which the detector is mounted are given on drawing 596-722-009.

The detector is attached to the detector cooler cold finger by means of four bolts. An indium shim is placed between the detector and the cold finger to increase the heat transfer rate between them. The ungrounded detector is electrically connected to two teminals on the dewar connector by means of 0.004 inch diameter constantan wire to reduce heat transfer.

The arrangement of the heater and sensor which control the cold head temperature are also shown on Figure 4.2.9.1. These components are both mounted with an indium shim also. Electrical connections are made to the instrumentation ring connectors with Teflon covered copper wire placed along the cold finger so as to tie down these wires thermally.

The bulb of a hydrogen vapor pressure thermometer is attached to the cold head by means of a single screw; an indium shim is again used. The tube leading to the gage is run down along the cold finger.

4.2.10 Detector Cooler

The Model 20 detector cooler was obtained from Cryogenic Technology Inc. (CTI), Waltham, Mass. and used to cool the Hg: Ge detector to about 26K. It consists of three units: a compressor and a temperature controller mounted in the receiver auxiliary stand and a refrigerator cold head mounted on top of the dewar in which the detector is housed (see drawings 596-722-003 and 596-722-016).

The compressor is connected to the cold head by two helium lines and a power line for the cold head motor; see Figure 4.2.10.1. The helium supply line to the cold head has an oil absorber in it. The temperature controller is connected to the heater and sensor through a plug on the instrumentation ring. The instrumentation ring also has a vacuum valve and a thermocouple vacuum gage attached to it.

The refrigerator cold head has a cold finger which extends down through an instrumentation ring into the dewar. The detector and temperature control heater and sensor are mounted on the bottom end of the cold finger.

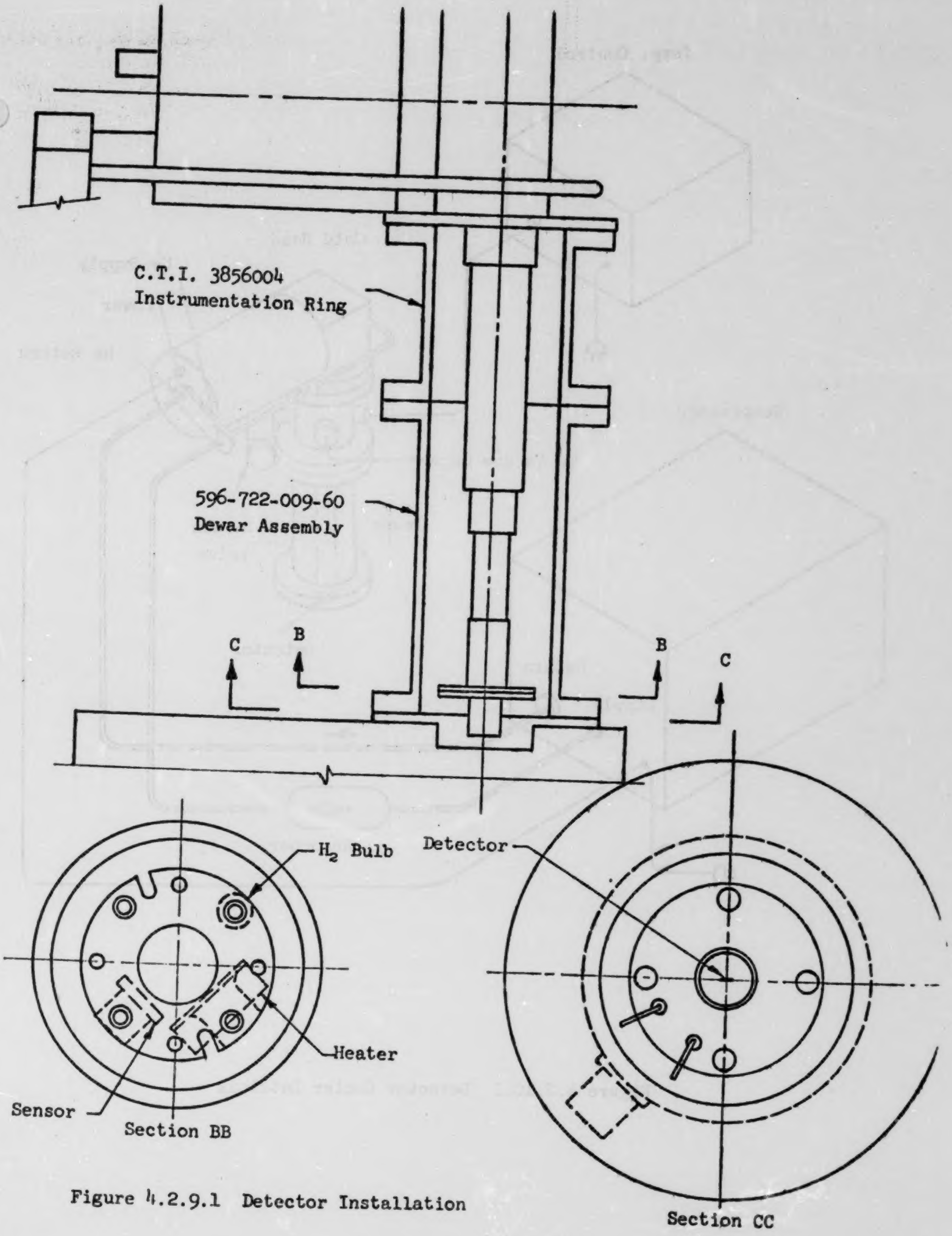


Figure 4.2.9.1 Detector Installation

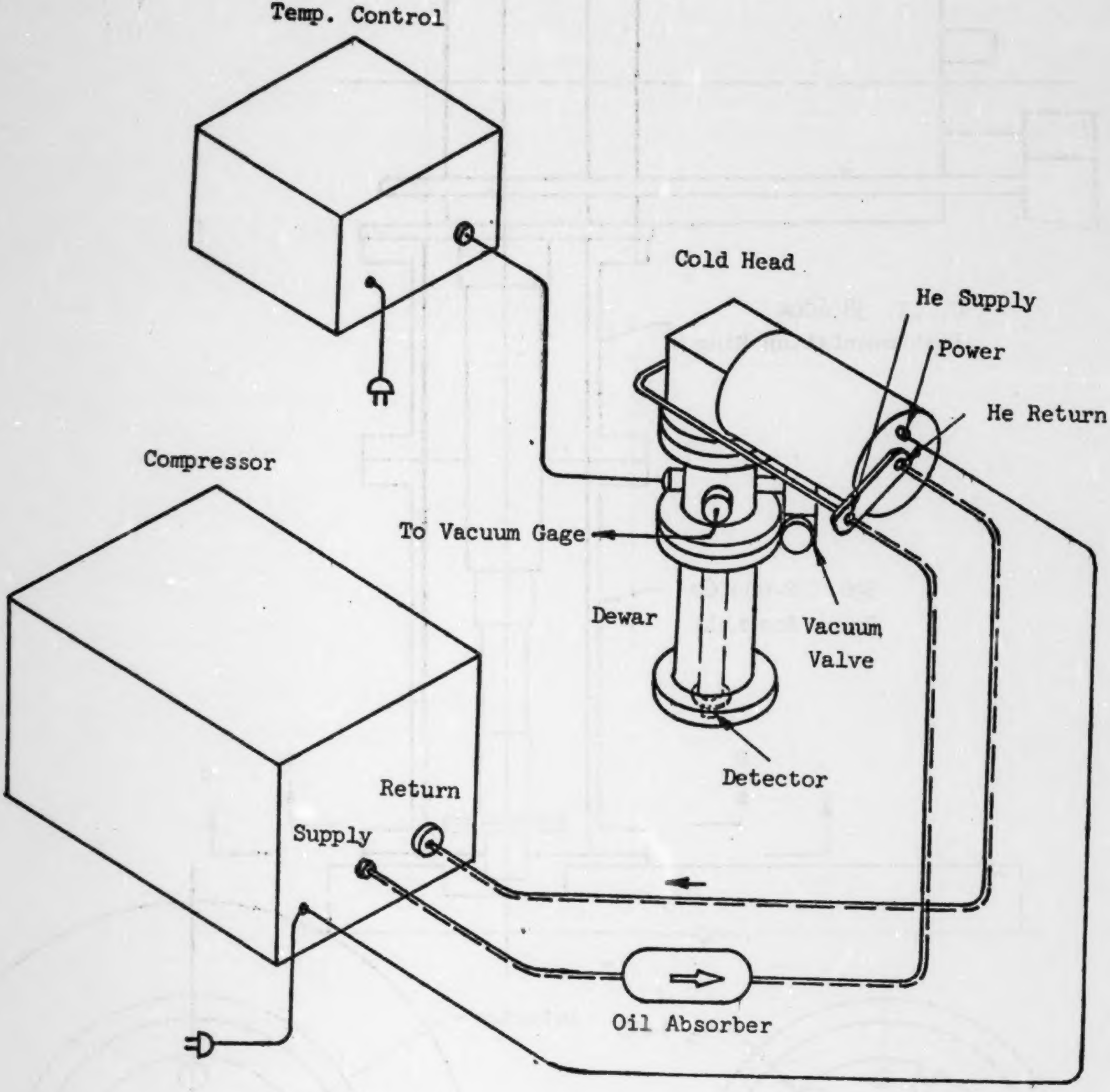


Figure 4.2.10.1 Detector Cooler Detaials

4.2.11 Synch Systems

The mechanical details of the source synch receiver assembly are shown on drawing 596-722-017. This assembly is attached by three screws to the receiver telescope near the front at about 45° from the top centerline on the right side looking toward the source. It should be noted that the shell of the detector was removed to increase its field of view.

The mechanical details of the reference synch light emitting diode (LED) and photodiode are shown on Figure 4.2.11.1. The LED and the photodiode are each mounted on a printed circuit board which are attached to the chopper housing. The LED board is identified by the letter "S" on the board upon which the LED is mounted and the photodiode is identified by the letter "D" on the board on which the photodiode is mounted. Care should be exercised if repairs are necessary to keep leads below the board faces since the clearance between the LED or diode and the chopper wheel is only about 0.032 inches.

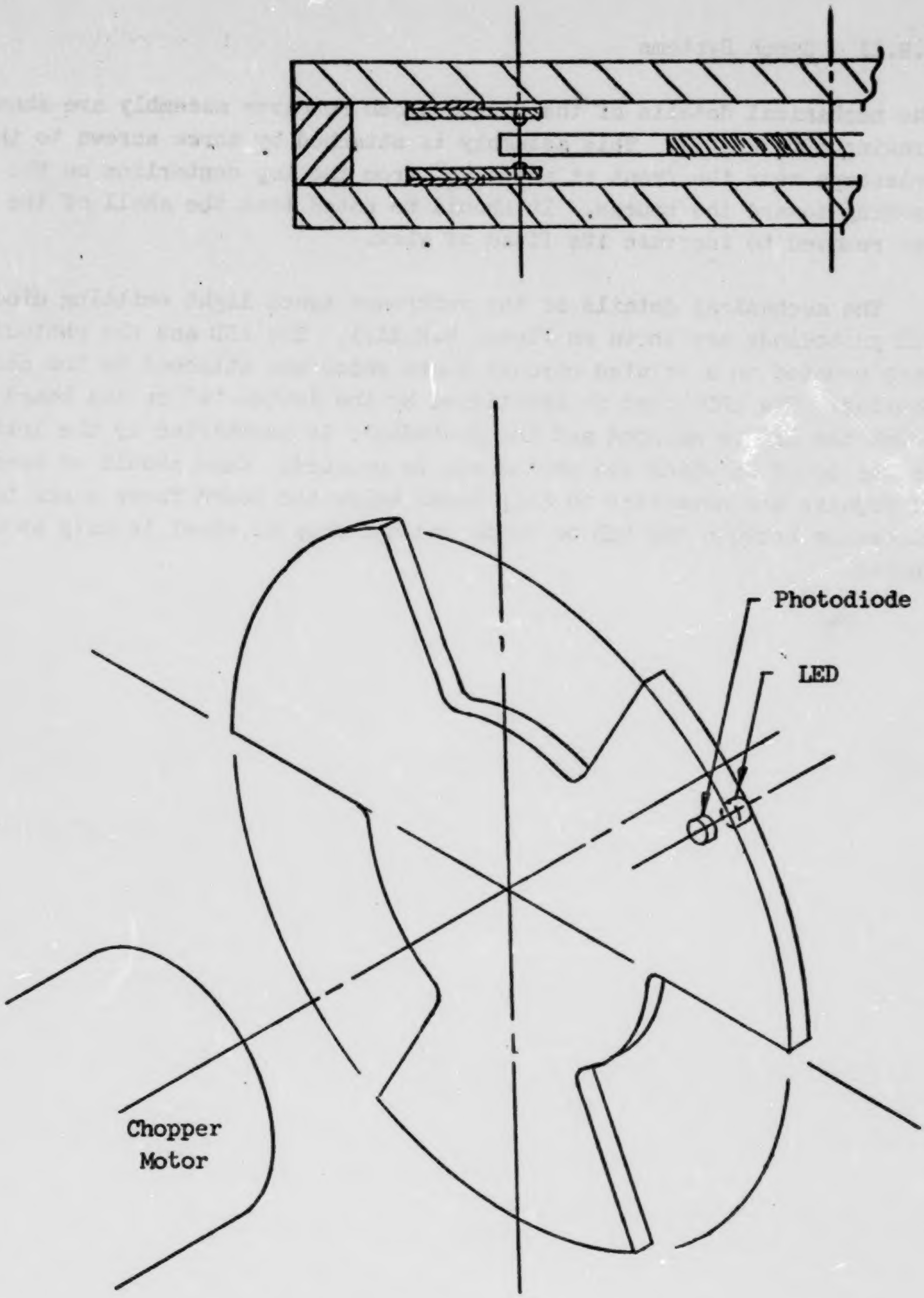


Figure 4.2.11.1 Reference Synch LED and Photodiode

4.3 ELECTRONIC SYSTEM DETAILS

4.3.1 The Electronic System

The electronic system design section gave a functional unit level description and the relation of each unit to the overall system. Here each unit is considered as an entity and described on the component level. There are two types of units described: units designed and manufactured by General Dynamics/Convair and vendor supplied equipment. GD/C equipment will be described in detail as to physical location, dimensional size, circuit operation and interconnections with references to schematic and pictorial diagrams which are included. Vendor supplied equipment will be described to the extent that it has been modified or particularly applies to the ROSE system. Direction to vendor manuals is given for mechanical and electronic details which are adequately described and are consistent with the present hardware.

Topic headings used in this section have a one to one correspondence to the system design section headings. For a functional description or the units relationship to the system, refer to the corresponding part of Section 3.6.

4.3.2 Signal Sources

There are four signal sources associated with the instrument. A Hg:Ge detector generates the source and reference signals. Two synch signals are generated to provide frequency and phase reference for the signals. Additionally, an encoder is used to generate pulses that are converted to a wavenumber representation.

Source and Reference - Hg:Ge

This signal source is predominantly optical in nature and the details given here relate only to its electrical characteristics. For a further description refer to the optical details section of this document. The bias requirement of this detector is 1 ma, which is supplied through a 10K ohm 1% precision resistor (Figure 4.3.2.1) and a low pass filter to the +23.6 volt supply in the preamplifier. The filter was added to reduce hum.

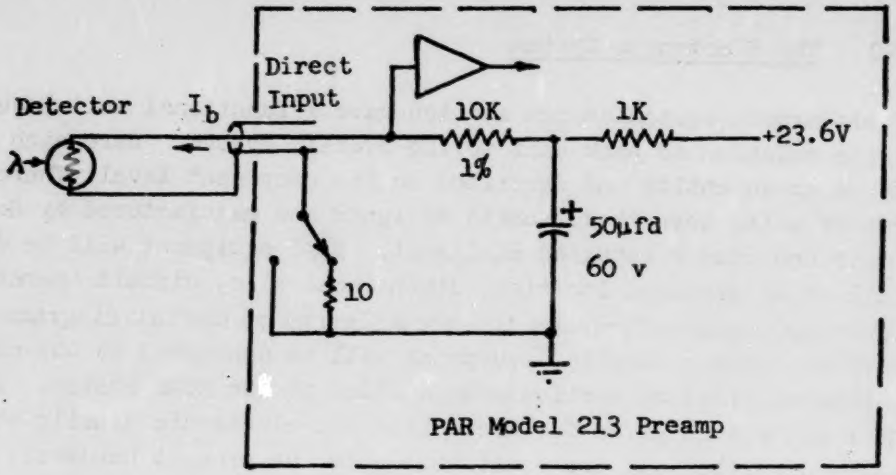


Figure 4.3.2.1 Detector Circuitry

The impedance of the detector is nominally 12.6K ohms and the detector is connected by a coax cable directly to the high impedance input of the PAR Model 213 preamplifier. The shell of the input connector may be connected either to ground directly or, to reduce ground loop current, to ground through a 10 ohm resistor by means of a switch on the rear of the preamplifier.

Source and Reference Synch Detectors

The purpose of these two detectors is to provide a signal which can be amplified into saturation to provide a synch signal for the lock-in amplifiers.

The source synch detector is an Electro-Nuclear Laboratories, Inc. Type 632 Indium Arsenide (InAs) photovoltaic detector. The detector is mounted on the receiver telescope housing and intercepts a portion of the source beam. The 1.5 mm active area is insufficient to provide adequate signal in the long path conditions. Therefore, it is mounted behind a collecting lens system. The detector has an impedance of 20 ohms which is transformer coupled up to 100 KΩ by a UTC A27 transformer which is located inside the receiver stand. At this point the output of the transformer drives a preamplifier (see the next section). The only electrical connection to the detector is a coaxial cable that carries the signal to the transformer.

The reference synch detector is a Hewlett Packard (H.P.) 5082-4205 Photo Diode. It is located opposite a H.P. 5082-4107 GaAs infrared source and both are perpendicular to the plane of the reference chopper which passes between them. The source emits in a narrow spectral region around 0.9μ which is near the peak response of the photo diode. The source is forward biased by connecting it through a 68Ω resistor to +6 volts. Forward current in the source is 80mA, producing an emittance near 80% of peak. The reference synch detector diode is reverse biased by connecting it to -15 volts through a 51K ohm resistance. The interconnections for the reference synch detector are schematically represented in Figure 4.3.2.2. While the source synch signal requires preamplification the reference signal is large enough that it is directly connected to the synch amplifier in the console.

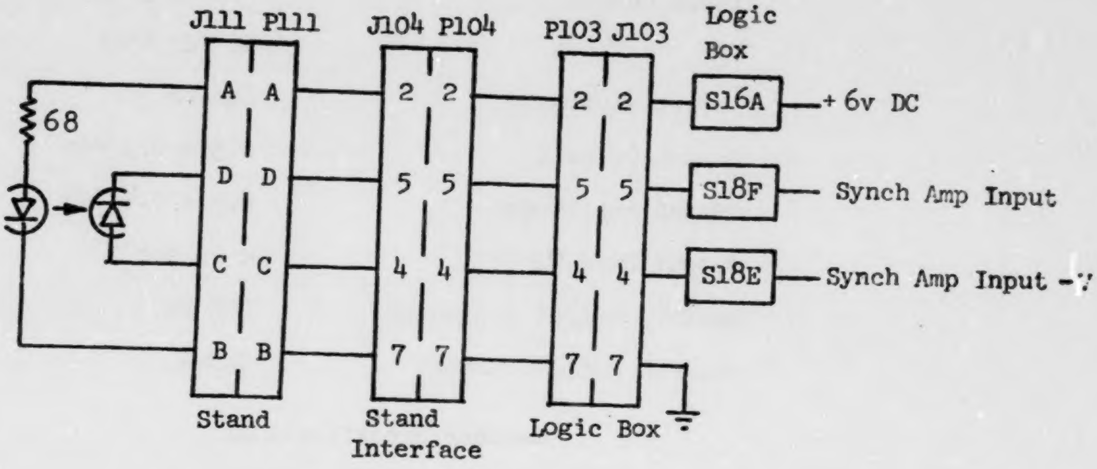


Figure 4.3.2.2. Reference Synch Detector

Wavenumber Generation - Shaft Encoder

A Dynamics Research Corporation Model 35 digital incremental shaft encoder is the signal source used to generate wavenumber. The particular encoder used generates nine thousand pulses per encoder shaft revolution, which is also one shaft revolution of the monochromator (see mechanical details section). These pulses in conjunction with the wavenumber logic provide wavenumber input information to the counter. The encoder itself generates sine waves on two lines which have a 90° phase relationship. An electronics option provided on the encoder senses the phase relationship and gives output pulses on the C.W. output for C.W. rotation and on the C.C.W. output for C.C.W. rotation. The complete part number including the optional electronics is 35-1-001-900. The appropriate specifications for this part number are tabulated in the table below. Figures 4.3.2.3 and 4.3.2.4 give the interconnections of the encoder to the system and encoder dimensions respectively:

Input Voltage:	+6 ± 0.3 Vdc
	-6 ± 0.3 Vdc
Input Current:	+6 Vdc 390mA
	-6 Vdc 45mA
Output Waveform:	Square
Output Offset:	0.3 ± 0.3 Vdc
Output Amplitude:	5.9 ± 0.4 Vdc
Output Rise Time:	< 2μ sec
Maximum Output Frequency:	20K Hz
Maximum Output Current:	0.5mA

Encoder Specifications

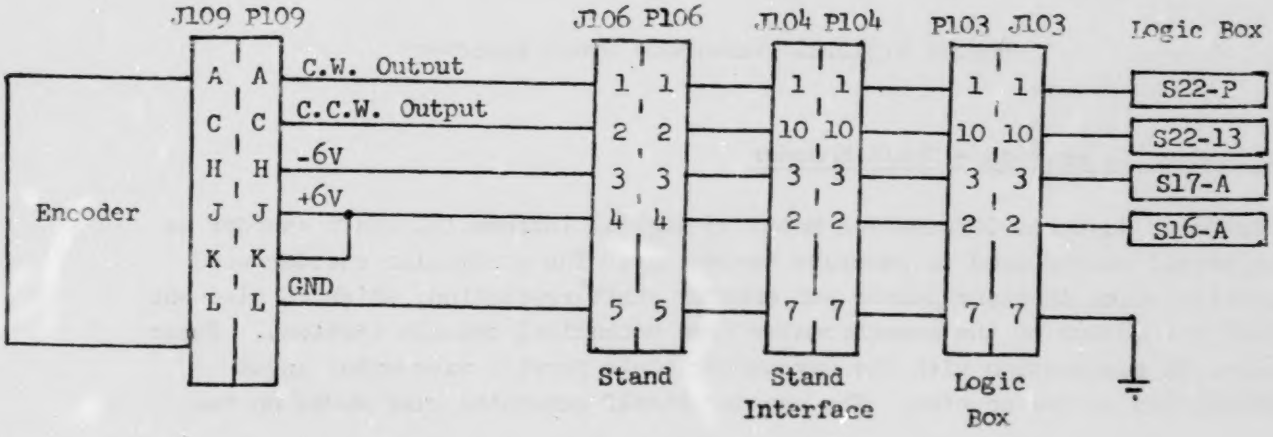


Figure 4.3.2.3 Encoder Interconnections

From the above specifications and interconnection diagram it can be seen that the encoder output directly drives the counting logic and that sufficient drive exists so that no signal conditioning is required.

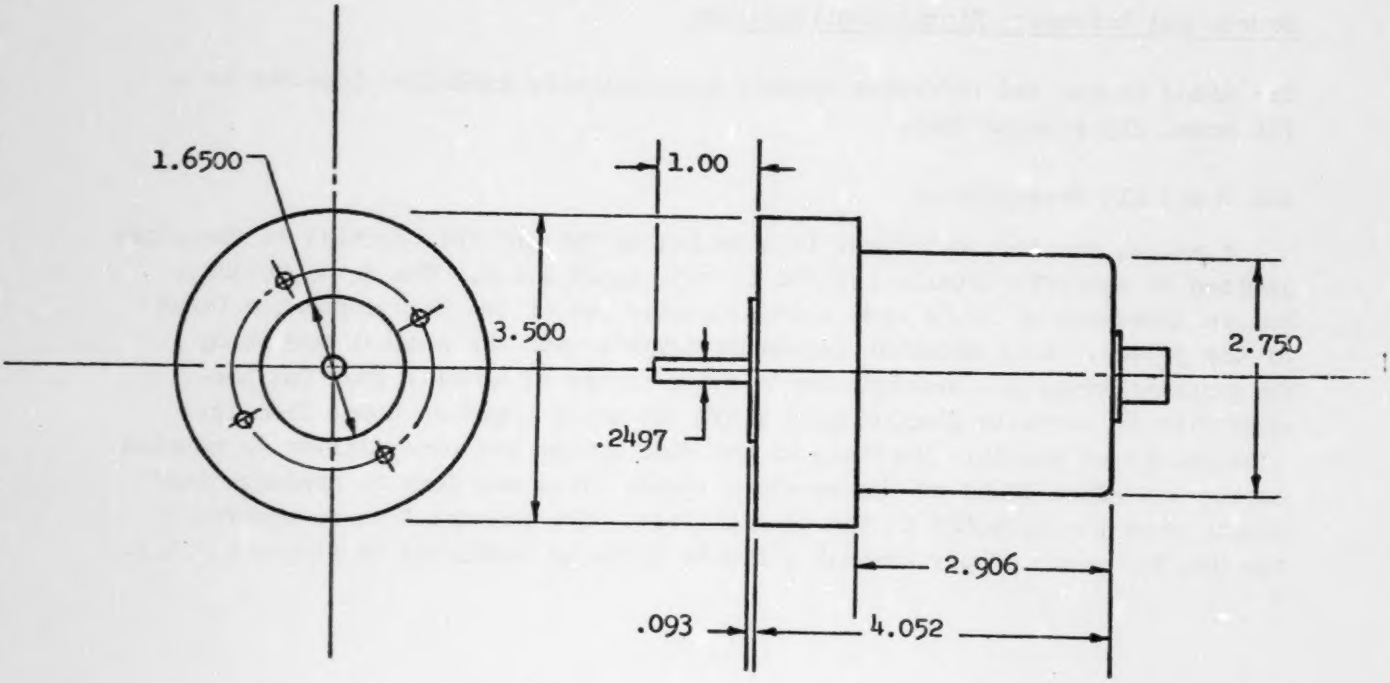


Figure 4.3.2.4. Encoder Dimensions

4.3.3 Signal Amplifiers

In a manner similar to that used in the electronic design section, the source and reference amplifier chains are treated in a separate subsection from the synch signal amplifiers. Again the paragraph numbers correspond to the numbers in the design section where the system relationships are discussed.

Source and Reference Signal Amplification

The mixed source and reference signals are initially amplified together in a PAR Model 213 preamplifier.

PAR Model 213 Preamplifier

A manual for the instrument is supplied by PAR and this section is therefore limited to specific details related to this application. The Hg:Ge detector has an impedance of 12.6K ohms which dictates use of the high impedance input of the preamp. This detector impedance coupled with the nominal operating frequencies gives the preamplifier a noise figure of about 2 db. The preamplifier is normally plugged into a NIM BIN which supplies power from its integral power supply. However, in the ROSE system the preamplifier is mounted on the interface panel of the receiver stand. This was done to minimize lead length from the detector to the preamplifier. The preamplifier is powered by the NIM BIN power supply through a remote cable as indicated in Figure 4.3.3.1.

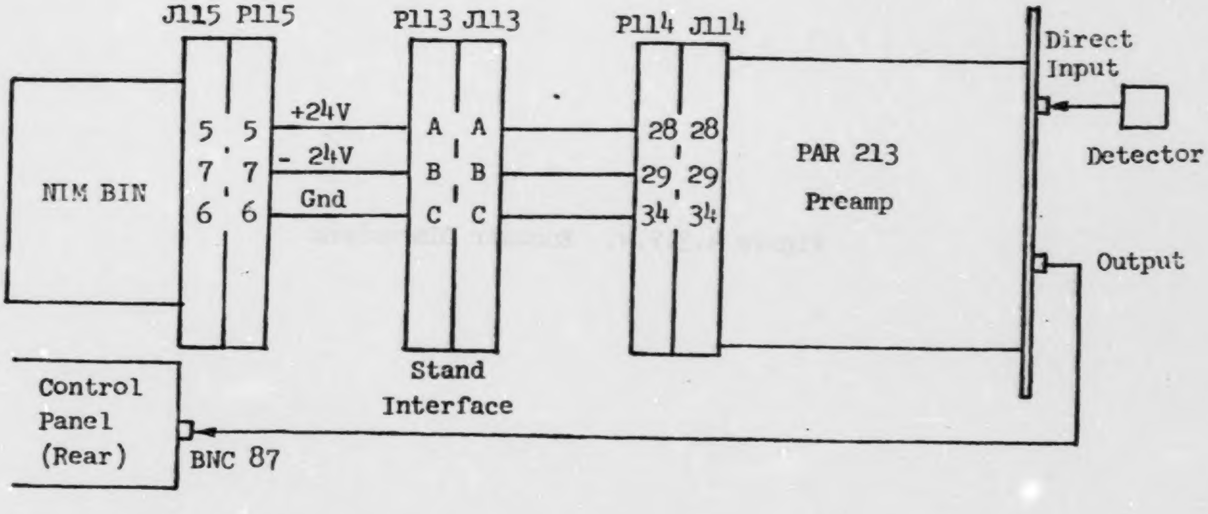


Figure 4.3.3.1 Preamplifier Interconnections

The output of the preamplifier is a BNC front panel connector. The output is connected by coaxial cable to BNC No. 87 on the rear of the control panel, at which point it is connected to the "operate" position of the STD. SIG - OPERATE switch. The wiper of this switch (in the "operate" position) connects the preamplifier output to BNC 88 on the control panel from which the signal goes to the input of the selective amplifiers.

PAR Model 210 Selective Amplifiers

A vendor supplied manual covers most of the detailed information of these amplifiers and should serve as the primary source. The details here relate only to the specific application information. Two Model 210 amplifiers are used in the system and they are located in the console NIM BIN. Only the signal wiring is of concern as they obtain power from the integrated supply in the NIM BIN. The source selective amplifier (which is mounted at the left looking at the front of the console) has its BNC input at the rear connected to the wiper of the STD. SIGNAL - OPERATE switch (i.e., calibrate or preamplifier output). The connection is made through a coaxial cable to BNC No. 88 on the control panel which is connected to the switch wiper. The BNC labeled "input" on the front panel is in parallel with the rear panel BNC and is used to jumper the input signal to the reference selective amplifier input. The selective amplifier outputs of interest here are the resonance outputs. This output is the signal, with a bandwidth determined by the "Q" setting, at the frequency to which the selective amplifier is tuned. These outputs are connected by coaxial cable to the signal input BNC connectors of the respective lock-in amplifiers. These signal connections are illustrated in Figure 4.3.3.2.

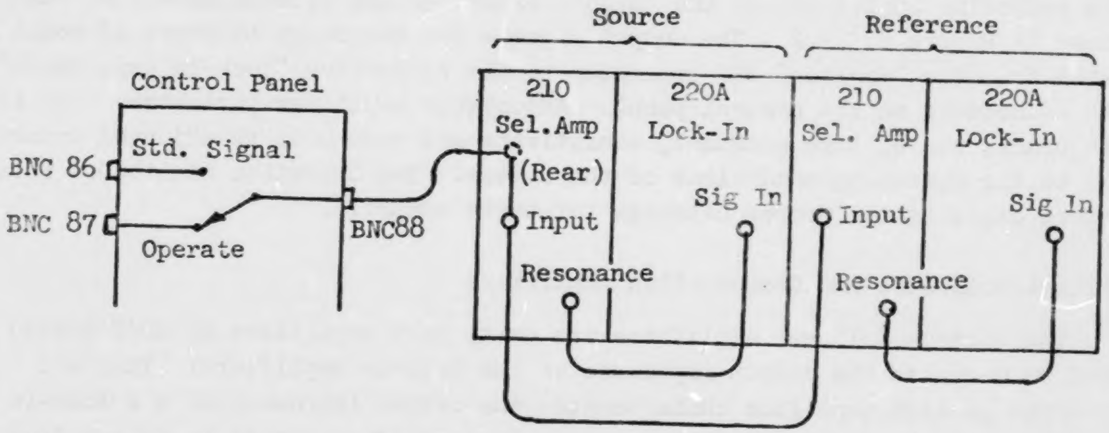


Figure 4.3.3.2. Selective Amplifier Signal Connections

The "Q" value used should be selected with two factors in mind. First, the function of the selective amplifiers is to provide signal separation and to prevent overload of the lock-in amplifiers. This would indicate the use of a high value of Q. However, gain stability is inversely related to Q and stability is important. Since the selective amplifier response time increases with Q a maximum value exists which is a function of scanning speed. Selection of the proper Q setting is discussed more fully in the Operation section.

PAR Model 220A Lock-In Amplifiers

The Model 220A was not a standard PAR amplifier at the time this instrument was designed. It was a significant modification of the Model 220. As a consequence the front panel markings and manual supplied were for the Model 220. Specifically in the modification, overload capability, sensitivity and long time constants were sacrificed in favor of low noise and baseline stability. This resulted in a much better amplifier for this application, because of the frequent occurrence in this application of signals that are a small percentage of full scale.

Templates were made to attach to the front panel so that the true values of sensitivity and time constant are indicated. The manual has been updated by the inclusion of a note page and "marking up" the manual to indicate the changes. This allows the manual to be considered the prime source of detailed information related to the lock-in amplifiers. Power for the lock-ins is again supplied by the NIM BIN power supply. External wiring associated with the amplifiers consists of only input signal, synch signal, and output signal coaxial cables. Input signal cables connect the resonance output of the selective amplifiers to the "signal input" of the lock-in amplifiers as shown in Figure 4.3.3.2. The output signals are connected by means of coaxial cable from the "monitor" BNC connector to the respective "lock-in amp. input" BNC connectors on the control panel. Adjustable amplifier parameters such as frequency, phase, time constant, sensitivity and mode must be adjusted according to the operating conditions of the system. The Operation section of this report explains the proper settings for these controls.

Voltage Followers and Compensation Amplifiers

The voltage follower amplifiers are unity gain amplifiers of GD/C design used to decrease the output impedance of the lock-in amplifiers. They are inserted in each amplifier chain because the output impedance of the lock-in amplifiers is 5K ohms while the compensation amplifier should be driven from less than 50 ohms. A circuit board located at S19 in the logic box contains both the voltage followers as well as the compensation amplifiers. For this reason they are discussed and illustrated as a single amplifier. A schematic diagram of the combined voltage followers and compensation amplifiers appears as Figure 4.3.3.3. Drawing 596-722-027 contains a schematic, component layout and connector wiring. Reference to Figure 4.3.3.3 is made in the text on circuit operation, while trouble shooting would require the drawing for component location purposes.

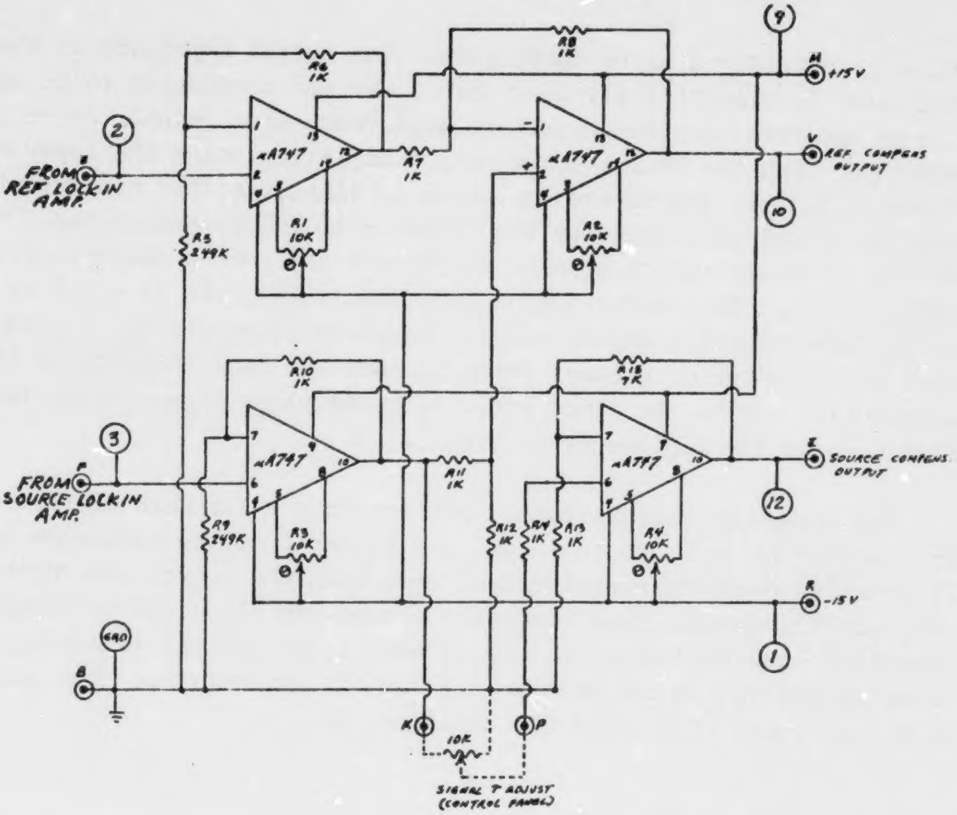


Figure 4.3.3.3. Source and Reference Compensation Amp

The two voltage followers use one Fairchild μA747C dual operational amplifier. The inputs to the voltage followers from the lock-in amplifiers are to the non-inverting input. The resulting gain is

$$A = 1 + \frac{Rt}{Ro} = 1 + \frac{R6}{R5}$$

$$A = 1 + \frac{1K}{249K} = 1.004$$

which is considered to be unity gain. The output impedance of the voltage followers is significantly less than 1 ohm and considered to be zero. The source and reference compensations amplifiers also jointly share a μA747C amplifier with the source compensation amplifier being the lower one in Figure 4.3.3.3. The source amplifier is simply another non-inverting amplifier, with the input controlled by the SIGNAL τ ADJUST potentiometer. The source voltage follower output appears at (K) and the source compensation amplifier input at (P). The source compensation amplifier gain is eight as determined by the non-inverting amplifier gain equation given above. A gain of eight is used for a number of reasons which include the dual chopping of the source, signal loss due to the atmospheric path and vignetting. These factors are discussed in the Radiometry section 3.3.3.

The reference compensation amplifier is a unity gain differential amplifier. Its purpose is to "decontaminate" the signal from the reference voltage follower which contains contributions from both the source and reference beams. The undesired source beam component can be cancelled out by using a nearly identical component from the source beam in an initial balancing procedure. Refer to the Radiometry section 3.3 for further details. The gain at the inverting input (Pin 1) of the amplifier is

$$A = \frac{Rf}{Ro} = \frac{R8}{R7}$$

$$A = 1$$

while the gain at the non-inverting input (Pin 2) is

$$A = 1 + \frac{Rf}{Ro} = 1 + \frac{R8}{R7}$$

$$A = 2$$

A voltage divider R11 and R12 is used to reduce the input to Pin 2 by one half. Thus, the gain of both inputs with respect to the voltage follower outputs is unity as desired.

All the resistors in this circuit are 1% metal film resistors for gain stability. The potentiometers R1, R2, R3 and R4 are ten turn potentiometers used to adjust the offset of each amplifier to zero. The circled numerics are the test points located on the circuit board, while the alphanumerics are the pins on connector S19. The output impedance of the compensation amplifiers is less than 1 ohm allowing the amplifiers to directly drive the data acquisition system. The interconnection of this circuit to the system is adequately documented in the wiring tables.

Synch Signal Amplification

There are two synch signals: the source synch and reference synch. The source synch signal is amplified in a chain consisting of a coupling transformer, source synch preamp, 120 Hz gyrator, and source synch amplifier. The reference synch signal is simply amplified by the reference synch amplifier.

Coupling Transformer

The output of the In As source synch detector is connected by a coaxial cable to the input of an impedance matching transformer. The transformer a UTC Type A27 with A-33 shield serves two purposes. First, it provides an approximate match of the 50 ohm output impedance of the detector to the source synch preamplifier input impedance of 1 megohm. It also serves as a low noise signal amplifier.

The A-27 as installed in this application has a primary impedance of 50 ohms and a secondary impedance of 100K ohms. The voltage gain (primary to secondary) is 45 which produces a worst case signal significantly above the preamplifier noise level. The transformer is physically located inside the receiver assembly stand. The output of the transformer is connected by coaxial cable to the source synch preamplifier.

Source Synch Preamplifier

The source synch preamplifier is a GD/C designed circuit used for low noise amplification of the source synch signal. It must provide a synch signal of sufficient amplitude so that signal to noise ratio will not be degraded by the gyrator or other following circuits not designed for low noise operation. Physically the preamplifier is in a mini chassis shared with the gyrator and located in the receiver assembly stand. Input signal is from the coupling transformer and its output is the fed to the gyrator. Figure 4.3.3.4 is a schematic of the preamplifier and is referred to in the discussion. For trouble shooting and component layout information drawing 596-722-023 should be utilized.

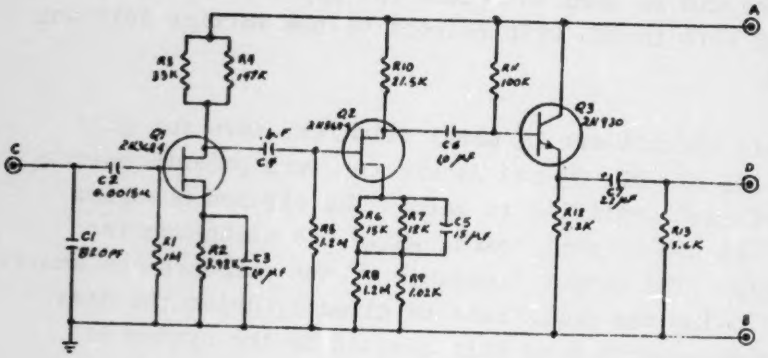


Figure 4.3.3.4. Source Synch Preamp

The first two stages of the preamplifier are JFET common source amplifiers, while the output stage is an emitter follower. The parallel resistances in the circuit like R3 and R4, R6 and R7, R8 and R9 should be considered as a single resistor with the equivalent value. The parallel components simply reflect late changes due to the addition of the coupling transformer. The gain in the first stage is found by the expression

$$AV_1 = \frac{gm1}{gos + GD}$$

where gm1 = actual gm from transconductance vs drain current curve for a 2N3684

gos = output conductance from output conductance vs drain current curve

GD = load conductance

I_d = 0.5 ma

The gain of the first stage is;

$$AV_1 = \frac{1100}{3 + 38} = 27$$

The second stage gain is modified by the unbypassed source resistance and is found by the expression

$$AV_2 = \frac{gm\ Ros\ R_d}{Ros + (gm\ Ros + 1)\ R_s + R_d}$$

where gm = actual gm from gm vs I_d curves

Ros = output resistance

R_d = load resistance

I_d = 0.3 ma

R_s = unbypassed source resistance

The gain of the second stage is

$$AV_2 = \frac{850\ \mu\text{mho} \times 400K \times 21K}{400K + (850\ \mu\text{mho} \times 400K + 1).55K + 21K}$$

$$AV_2 = 12$$

With the emitter follower gain of one the total preamplifier gain is 324. The amplifier is broadband but the predominance of 120 Hz noise overshadowed its inherent low noise capability. This necessitated the use of a narrow band filter. Using a gyrator required a relatively high input impedance for stability. The large value of emitter resistance in the emitter follower reflects this requirement. Input, output and power line interconnections associated with the preamplifier are shown in Figure 4.3.3.5.

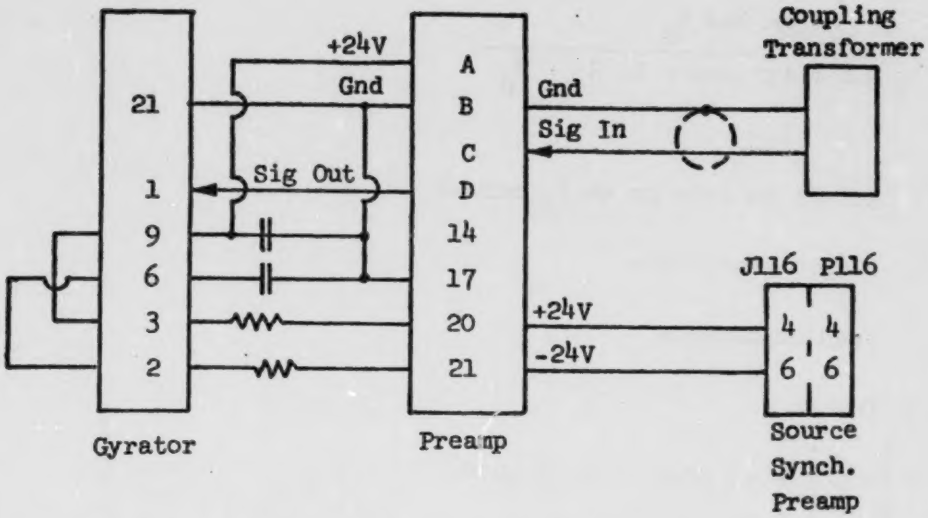


Figure 4.3.3.5. Source Synch Preamplifier Interconnections

120 Hz Gyrator

The gyrator circuit is contained along with the source synch preamplifier in a mini-chassis located in the receiver assembly stand. Its primary purpose is to filter out 120 Hz noise from the source synch signal. 120 Hz gyrator is a misnomer; it is really a notch filter using a gyrator as the active element. Circuit diagram Figure 4.3.3.6 shows three operational amplifiers, two of these are contained in one dual-in-line package. The μA747 is a Fairchild Semiconductor dual operational amplifier with internal frequency compensation. A μA741 is identical to $\frac{1}{2}$ of a μA747. The two halves of the μA747 form the notch filter while the μA741 is an inverting amplifier providing gain and a low output impedance. Simple interpretation of a nomagraph included with an application note gives the value for the frequency determining

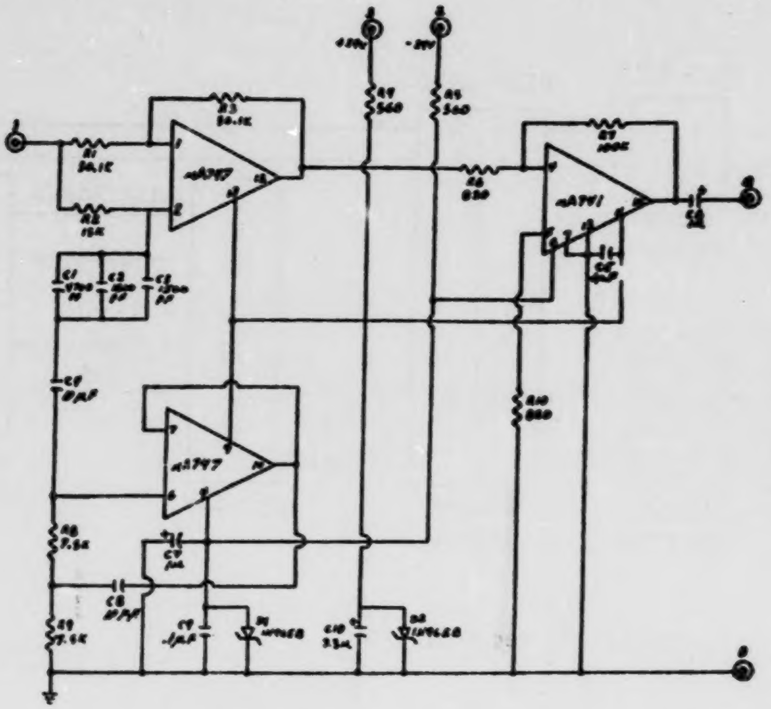


Figure 4.3.3.6. 120 Hz Gyrator

capacitance of C1, C2 and C3 in parallel. Parallel capacitors were used to obtain the required .035µfd because the value is quite critical in this high Q circuit. Zener diodes D1 and D2 along with their bypass capacitors C9 and C10 provided a ±12 volts D.C. power supply for the operational amplifiers. The inverting amplifier has gain equal to 120 and output impedance less than 0.5 ohms.

Drawing 596-727-024 should be referred to for component layout and connector information on this circuit. Interconnection of the gyrator to the system is illustrated in Figure 4.3.3.7. The input signal is the output of the preamplifier while the output is cabled to the console and becomes the input to the source synch amplifier.

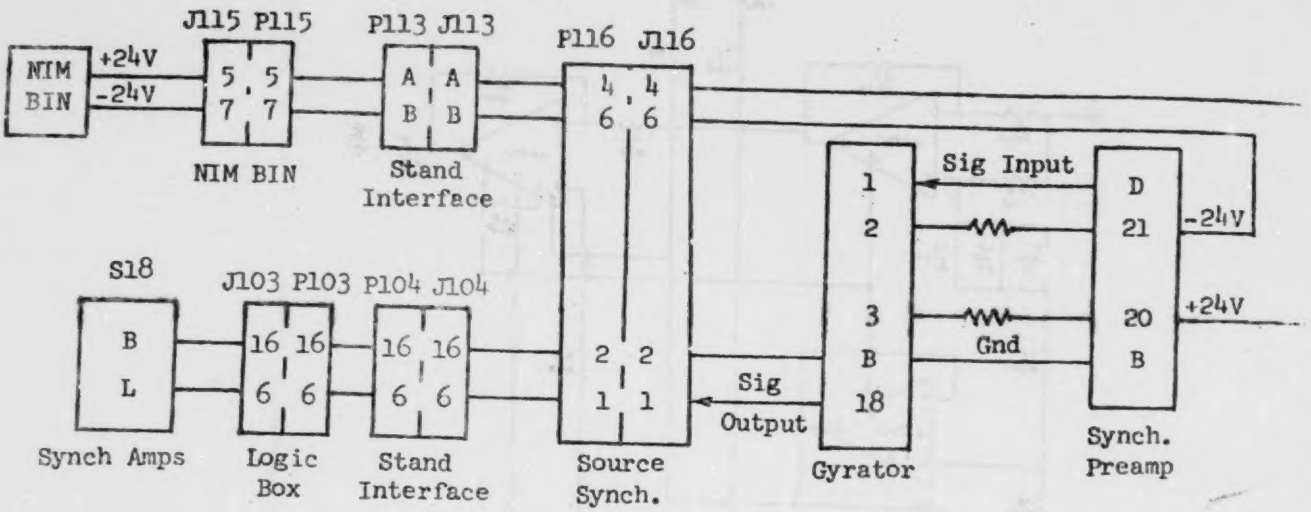


Figure 4.3.3.7. Interconnection of Gyrator

Source Synch Amp

The source synch amplifier is physically located in the logic chassis of the console. It shares a circuit board located in S18 with the reference synch amplifier. A schematic showing both the source synch amplifier and reference synch amplifier appears as Figure 4.3.3.8. The lower amplifier consisting of two operational amplifier stages is the source synch amplifier.

Drawing 596-722-026 shows component locations and the combined schematic diagram. Use of this drawing will facilitate trouble shooting and amplifier offset adjustment.

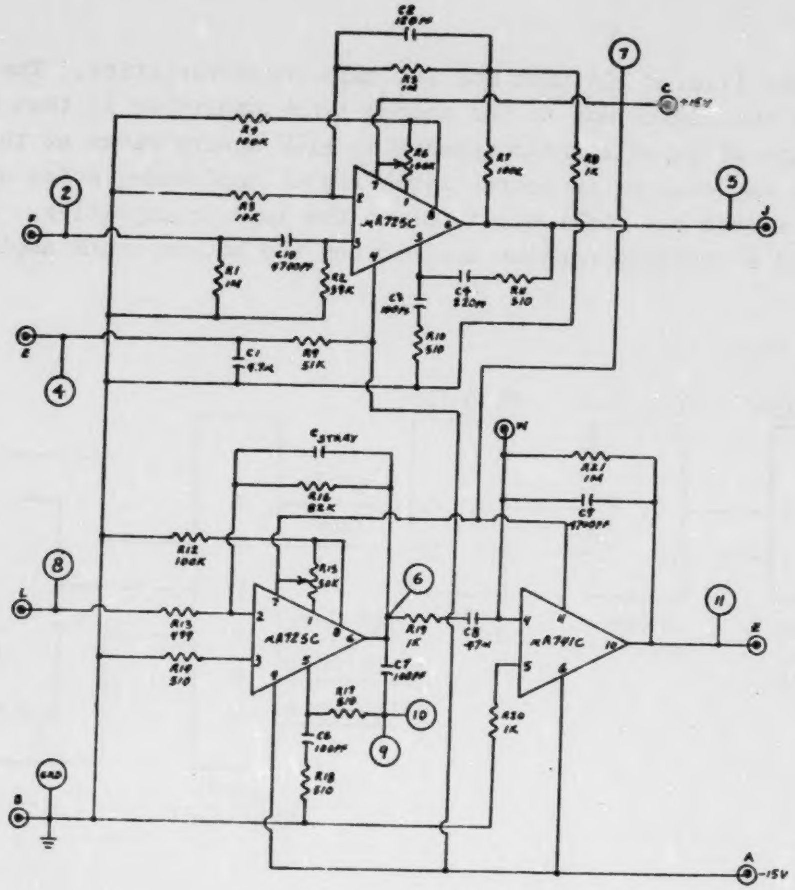


Figure 4.3.3.8. Source and Ref. Synch Amplifiers

The first stage is a high gain inverting amplifier using a μA725 instrumentation amplifier. This gain, determined from the inverting amplifier gain formula is 160. Capacitor C5 which bypasses the feedback resistor makes the amplifier a low pass filter. The corner frequency of C5 and R16 determines a pass band from zero to 720 Hz. Components C6, C7, R17, and R18 make up the frequency compensation network for the μA725. Variable resistor R15 is the offset adjustment and may be adjusted to optimize the output for various input conditions. The output of this stage drives the inverting input of the μA741 through R19 and C8. R19 and C8 are a high pass filter with a corner frequency at 340 Hz. At this point in the amplifier chain the signal is saturated or near saturation meaning the amplitude is ±14 volts D.C. The gain in the second stage is generally academic but would be 1000 up to the corner frequency determined by C9 and R21. This corner frequency is rather hard to determine because input to output capacity is significant compared to 100 pf; it is approximately 1KHz. This stage is more important for the low output impedance it provides (i.e.,< 1Ω) than for its gain characteristics. The overall effect on the signal due to the source synch amplifier is that the complete range of input signals appears as ±14V square waves at the output. Therefore any changes in source synch signal amplitude, noise or wave shape does not affect the reference input to the lock in amplifier. Figure 4.3.3.9 is an interconnection diagram for the source synch amplifier.

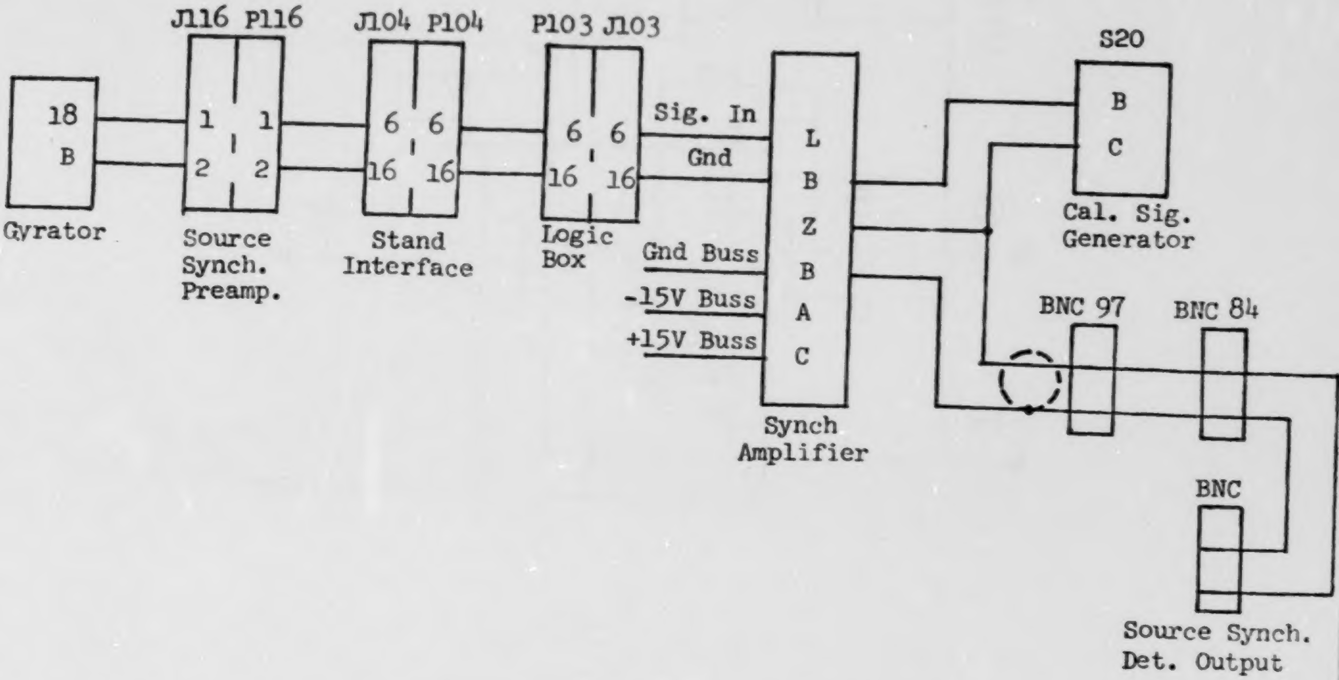


Figure 4.3.3.9. Source Synch Amplifier Interconnections

Reference Synch Amplifier

Input to this amplifier is the reference synch signal generated by the Ga As diode detector associated with the reference chopper. The output from this detector is of sufficient amplitude so that a single operational amplifier stage will provide adequate signal. This circuit is located at S18 in the logic box of the control console. It shares this circuit board with the source synch amplifier. For this reason it also shares a schematic diagram, Figure 4.3.3.8 in this section, and Drawing 596-722-026. The top half of Figure 4.3.3.8, the single μA725 instrumentation amplifier is the reference synch amplifier. It is an inverting amplifier using proportional feedback. Gain of the amplifier is a function of the voltage divider on the output as well as the feedback ratio. An expression for the gain is

$$A = \frac{R_{OUT}}{R_{SEN}} \cdot \frac{R_f}{R_{IN}} = \frac{R7 + R8}{R8} \cdot \frac{R5}{R3}$$

$$A = \frac{100K + 1K}{1K} \cdot \frac{1M}{10K} = 10^4$$

This gain figure of 10^4 is restricted to frequencies within the amplifier pass band. Capacitor C10 and resistor R2 set the low frequency corner at 870 Hz. Capacitor C2 and resistor R5 set a high frequency corner at 1300 Hz. All other components in the circuit do not reflect on the gain. The network consisting of C3, C4, R11 and R10 is the frequency compensation network for the μA725. Variable resistor R6 which is mounted on the back of the S18 board is for offset control. Biasing and coupling characteristics of the input signal determine an optimum operating point. Operating point or offset is controlled by R6. It should be adjusted for an output square wave with minimum noise and rise time. The network consisting of R9 and C1 provides a return path and supply voltage filtering for the HP4205 diode detector. The output of this circuit serves as the reference lock-in amplifier's reference signal and also provides reference frequency input to the calibration signal generator.

Figure 4.3.3.10 gives the interconnection of this circuit to the system.

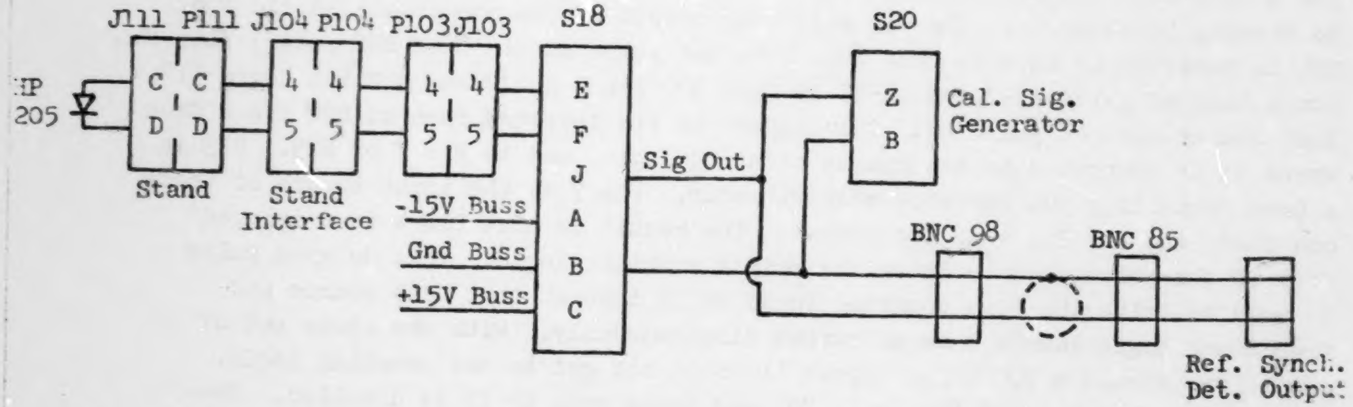


Figure 4.3.3.10. Reference Synch Amplifier Interconnections

4.3.4 Wavenumber Generation

The system design section of the document discusses the theory of the design and should be referred to for an understanding of overall operation. In this section block portions of the logic associated with wavenumber generation will be discussed in detail. Drawing 596-722-032 is to be referred to in all paragraphs related to wavenumber generation. All board type numbers refer to the Data Technology part number.

Pulse Shaping Logic

The pulse shaping logic and all other logic functions related to wavenumber generation are located in the logic box of the control console. Circuit boards S22, S23, S24 contain the pulse shaping logic. Physical location of these boards inside the logic box may be found on the card layout diagram in the front of the wiring table. Inputs to the pulse shaping logic are the clockwise (CW) and counterclockwise (CCW) pulses from the shaft encoder. Clockwise pulses are connected to S22 Pin P and to S24 Pin N. Board S22 is a Data Technology circuit containing three quad dual gates. S22 Pin P is one input of a dual input nand gate while the other input Pin R is the output of dual gates wired as a flip-flop. Gate A2-S will go to "0" if both inputs P and R are "1". P is of course "1" at each CW input pulse. R is "1" if the previous input pulse was also a CW pulse. This results in an output at A2-S each time a CW pulse occurs preceded by a CW pulse. Pin R is held at one by consecutive CW input pulses. This is accomplished by having the input at Pin N of S24 trigger a monostable on its falling edge. Board S24 contains monostables used by the pulse shaping logic. These monostables share board S24 with the Data Control monostable. For a schematic diagram refer to Figure 4.3.4.1 and for component layout refer to drawing 596-722-031. The 4.5 μsec wide output of the monostable at Pin P of S24 is inverted by A3-U on S22. This inverted pulse at Pin U of S22 sets a flip-flop consisting of gates A3-Z and A2-22 so that S22 Pin Z and hence, S22 Pin R are "1". Each consecutive CW pulse will then appear in its inverted form at S22 Pin S from where it is connected to the coarse counting logic, and to Pin 7 of S23. S23 is a Data Technology 540 one shot multivibrator. Pin 7 is the input to one of these one shots and has Pin 4 as the output. The result is that Pin 4 is a delayed form of the pulse used to drive the coarse counting logic. This delayed pulse is used to drive the fine counting logic which insures that both coarse and fine count logic cannot have an output simultaneously. With the above set of conditions should a CCW pulse appear it would not get to the counting logic. This is true because S22 Pin 14 is "0" and hence gate A2-15 is disabled. However, similar to the CW pulses this first CCW pulse trailing edge would set the flip-flop so that S22-22 would go to "1". This would then enable A2-15 and the next CCW pulse would reach the counting logic. The outputs of gates A2-5 and A2-15 are wired together forming a "wired OR" circuit. A "wired OR" is used because there is but one set of counting logic and it needs to be driven by both CW and CCW pulses. This dual utilization of the counting logic saves counters but necessitates a circuit to sense and remember which direction is providing input to the counters.

Direction Sensing Logic

The direction sensing logic consists of boards S22 and S23. They are Data Technology 502 quad dual gates and a 540 one shot monostable multivibrator respectively. The direction sensing logic serves two functions. First, it steers the output of the counting logic to the counter (X) input or counter (Y) input for CW or CCW encoder inputs respectively. CW rotation corresponds to an increasing wavenumber and bidirectional counter input (X) increments the count. CCW rotation corresponds to a decreasing wavenumber and the (Y) input decrements the counter. This results in the counter properly tracking the wavenumber. The second function of the direction sensing logic is to enable the resolution counter only during CW rotation to avoid backlash problems. This is accomplished by inverting the counter (X) input and using it to drive the resolution counter. Counting logic output steering is accomplished by use of a monostable and a dual input gate. The CW input line is connected to S23 Pin 13. This is a monostable input whose outputs are at Pins 19 and 12. Pin 19 is the input pulse stretched to 4.5 microseconds. Pin 12 is the "not" of Pin 19. The sum of the counting logic output is at S22 Pins 5 and 6 which are inputs to two different gates. S23 Pin 19 goes to S22 Pin 4 and S23 Pin 12 goes to S22 Pin 7. The result is that following a CW input pulse gate A1-3 of S22 will be enabled for 4.5 microseconds by the output of the monostable. All counting logic outputs would appear during this period at gate A1-3's input and be steered to the counter (X) output. If the counting logic output was due to a CCW pulse the "not" CW function at S23 Pin 12 would enable A1-8 of S22. This would then steer the output to the counter (Y) output. The resolution counter input is provided by inverting the output of A1-3. A1-3 is connected to Pin F of S22 which is the input to gate A1-J. The inverted signal at A1-J is then connected to the resolution counting logic input at S10-C.

Counting Logic

The purpose of the counting logic is to convert the 9K pulses per revolution outputted by the pulse shaping logic into the number of pulses per revolution set by the encoder control switches on the control panel. Each of these switches, "coarse", "tens", and "ones" controls a separate counter in the counting logic. The counting logic output will be the sum of the numbers set by the switches. The components of the coarse counting logic include two 528T binary counters, board numbers S11 and S12; S11 is the coarse counter for the 7-13.5μ region and S12 is the coarse counter for the 3-5.5μ region. A quad dual gate type 502T, board number S13 and a dual triple input gate type 503T, board number S8 sum the various binary outputs of S11 and S12 to form the proper factors. A quad inverter type 501T, board number S15 is used to reset the counters S11 and S12. The remaining components of the coarse counting logic are the two coarse selector switches, one for each spectral region, located on the control panel. The output of the pulse shaping logic "OR" gate at S22 Pin S drives both counter inputs located at S11 and S12 Pin C. The outputs of the counters are tied to gates so that a desired division factor is acquired. For example, the Q2 and Q5 outputs of S11 are summed by gate A1-8 of S13. After 18 input pulses both Q5 and Q2 will be "1" and A1-8 will go to "0" at its output. The output then resets the counter. Hence gate A1-8 will have an output every 18 input pulses which is equivalent to 500 pulses per shaft revolution. When the instrument is in the 7-13.5µ mode and if the 7-13.5µ coarse selector switch is in the 500 position the A1-8 output will be the coarse input to the counter. It must however be summed with the tens and ones counts in the counter output logic. The 529 coarse count associated with the 7-13.5µ region is formed by gate A1-3 of S13. The inputs to A1-3 are the Q5 and Q1 outputs of counter S11. Every 17 input pulses will produce an output at A1-3 and hence, 529 counts per shaft revolution. Counter S11 is reset by double inverting the wiper of the 7-13.5µ coarse selector switch. The wiper is connected to an inverter A2-7 of board S15 which has its output connected to A2-9 of S15. The output of A2-9 is tied back to pins 4, 8, 12, 16, L, R, V, and Z of the S11 counter and hence, resets the whole counter. The result is that counter S11 will divide the input 9K pulses by 17 or 18 depending on the selected 529 or 500 position of the coarse selector switch respectively. Counting output will be present at the switch wiper and be available for summing with the tens and ones counts. Counter S12 works in a similar fashion for the 3-5.5µ region. The division factors required for 1125 and 1286 counts are 8 and 7 respectively. A factor of seven is obtained by summing the Q1, Q2, Q3 outputs using gate A4-V on S8. A factor of eight is obtained by inverting the Q4 output with gate A1-J of S13. Resetting of counter S12 is again similar to the reset of S11. The wiper of the 3-5.5µ coarse selector switch is double inverted by gates A1-3 and A1-E of S15 and connected back to the reset lines Pins 4, 8, 12, and 16 of S12. Again the wiper will have the selected counts on it and be available for summing with the tens and ones counting logic output. Tens and ones counting logic uses the same technique as the coarse counting logic. The tens logic consists of two 528T counters, board numbers S5 and S6, three types of summing gates a 504T at (S7), 503T (S8) and a 508T (S9), inverter type 501T (S15) for counter reset and the tens selector switch on the control panel. Tens counts of 0, 10, 20, 30, 80, 90, 100, 110, 120, 130, 140, 150, and 160 are available to be selected by the selector switch. The discontinuity in values is accounted for by the total count requirements. When the instrument is operated in the 7-13.5μ region the total 0.1 wavenumbers per revolution will be between 500 and 560 with 520 being the nominal value experienced. The use of the 500 or 529 coarse count plus the 0, 10, 20, or 30 tens counts will cover this complete range of values. Operating the instrument in the 3-5.5μ region will require between 1210 and 1310 0.1 wavenumbers per shaft revolution. The coarse values 1125 and 1286 along with the tens made available will cover all cases in this range of values. The nominal value experienced was 1265 0.1 wavenumbers per revolution. Input to the tens counting logic is the delayed encoder pulse from the 540 monostable board S23 Pin 4. The input is connected to Pin C of the S5 counter. Input to the S6 counter is the output of the S5 counter meaning S5 Pin W to S6 Pin C. This serves to extend the length of the counter by two binary bits. Q1 and Q2 outputs of S6 then become effectively the Q9 and Q10 outputs of the tens counter. To summarize the following tens counting logic table is shown to provide input, gate and board information for each of the 10's counts.

Count/Revolution	Summing Gate		Counter Inputs
	Board Location	Gate	
10	S7	A1-H	Q2, Q8, Q9, Q10
20	S7	A1-3	Q1, Q7, Q8, Q9
30	S9	A1-9	Q1, Q2, Q4, Q6, Q9
80	S8	A1-F	Q1, Q6, Q7
90	S8	A1-3	Q3, Q6, Q7
100	S7	A2-N	Q2, Q4, Q5, Q7
110	S8	A2-L	Q2, Q5, Q7
120	S7	A2-8	Q1, Q2, Q4, Q7
130	S8	A2-7	Q1, Q3, Q7
140	S8	A3-R	Q1, Q7
150	S7	A3-U	Q3, Q4, Q5, Q6
160	S7	A3-13	Q1, Q4, Q5, Q6

Reset of the tens counting logic is similar to the coarse counting reset. When an output appears at the tens selector switch it connects through inverters to the reset lines. Specifically the wiper is connected to gate A2-14 on board S15. It is reinverted by gate A2-K and connected back to S5 Pins 4, 8, 12, 16, L, R, V, Z and to S6 Pins 4 and 8. Thus, with each tens output pulse the counter consisting of S5 and S6 is completely reset. The output pulses on the tens selector switch are also the tens counting logic output and are summed with the coarse and ones outputs in the counter output logic. The ones counting logic is nearly a duplicate of the tens counting logic. The input is the delayed encoder input from S23 Pin 4 to the counter input at S1 Pin C. The 528T counters at S1 and S2 form a single long counter with Q1 through Q6 of S2 actually being Q9 through Q14 of the combined counter. The summing gates of the ones counting logic are a 508T located at S3 and a 504T at S4. Counter reset is again provided by inverters 501T on board S15. The table below is provided to summarize the output count, summing gate board location, gate number, and the counter inputs to the gate.

	Summing Gate		Counter
Counts/Revolution	Board Location	Gate	Inputs
1	S4	A1-H	Q6, Q9, Q10, Q14
2	S4	A1-3	Q5, Q8, Q9, Q13
3	S3	A1-9	Q2, Q3, Q5, Q6, Q8, Q9, Q10, Q12
4	S4	A2-N	Q4, Q7, Q8, Q12
5	S3	A2-18	Q1, Q2, Q3, Q9, Q10, Q11
6	S3	A3-P	Q1, Q2, Q4, Q5, Q7, Q8, Q9, Q11
7	S4	A2-8	Q1, Q3, Q9, Q11
8	S4	A3-U	Q3, Q6, Q7, Q11
9	S3	A4-Z	Q1, Q2, Q3, Q6, Q7, Q8, Q9, Q10

Reset of the ones counting logic is similar to the coarse and tens counting logic reset. An output on the ones selector switch wiper occurs when all inputs to the selected gate are "1". Reset of the counters is then provided by double inverting this output and connecting it back to the counter reset inputs. In this case the ones wiper is connected to the input of inverting gate A3-M on board S15. Gate A3-P then reinverts this signal and provides reset to S1 and S2 Pins 4, 8, 12, 16, L, R, V, and Z. The ones output at the selector switch is summed with the tens and coarse counting logic output in the counter output logic.

Counter Output Logic

The counter output logic serves to sum the coarse, tens and ones counting logic outputs together. The result of this summing is the total count per revolution as dictated by the selector switches. The technique used is a two level "OR" circuit. The tens and ones counting output are first inverted then "ORed" together. The "OR" output then goes to two additional "OR" circuits where it is "ORed" with either the 7-13.5µ coarse or 3-5.5µ coarse counting logic output to form the total sum count. All the counter output logic is preformed by the quad dual gates on board S14. The tens count selector wiper is connected to an inverter gate A1-8 on S14 while the ones wiper is connected to inverter gate A1-J. The inverted tens and ones are then inputs to gate A1-C and A1-3 respectively. The outputs of gates A1-3 and A1-C are tied together to form a wired "OR". Pins 3 or C of S14 would then have the sum of the tens and ones counting logic output. The sum is then inverted by gates A2-5 and A3-Z.

The 7-13.5µ coarse counting output is inverted by gate A3-22 of S14 and the inverted counter is connected to the input of gate A3-V. A3-V is one gate of a wired "OR". The other gate is A3-17 which has as its input the sum of tens and ones from gate A3-Z. The resultant output on Pins 17 and V is the total count of 7-13.5µ coarse, tens, and ones counting logic. The 3-5.5µ coarse counting output is inverted by gate A2-15 and provides input to gate AZ-L, which is one half of an "OR". The other gate of the "OR" is gate A2-10 which has the summed tens and ones from gate A2-5 for its input. Pins 10 and L of S14 then are the total sum of 3-5.5µ coarse, tens, and ones counting logic. The two combined outputs at S14 Pin 10 and S14 Pin 17 are connected to the band selector switch on the control panel. The wiper of this switch will then connect the appropriate count to the direction sensing logic through inverting gate A1-C on board S22. The total count will then be steered to the (X) or (Y) input of the bidirectional counter by the direction sensing logic.

Resolution Selector Logic

The output of the logic to the bidirectional counter is a pulse every 0.1 wavenumbers. In many cases it is desired to take data at intervals other than 0.1cm^{-1}. The resolution selector logic enables the operator to acquire data at 0.1, 0.2, 0.3, 0.5, 1 and 2cm^{-1} intervals. To accomplish this the counting logic output is fed into another counting circuit which is controlled by a multiposition switch on the control panel. The output of the resolution selector logic is the input to the data control logic which is used to command the data acquisition subsystem to take data. Components of the resolution selector logic are a 528T counter on board S10, 502T quad dual gates on board S13, 501T inverter on board S15, and a 502 gate used as an inverter on board S22.

It is desired to take data only when the monochromator is scanning in one direction to avoid backlash problems. The direction of increasing wavenumber was selected and hence, the (X) input to the counter is used as the signal source. Counter (X) input on board S22 Pin 3 is inverted by gate A1-J or S22 and connected to the counter input, board S10 Pin C. This signal is also inverted by gate A3-22 on S13 and is connected to the resolution selector switch as the 0.1 cm^{-1} signal. Gates on S13 also sum the various outputs of the S10 counter to form the other resolution elements. The table below summarizes the resolution elements, their associated summing gates, and counter inputs to the gates.

Resolution Element Cm^{-1}	Summing Gate Board Location	Summing Gate Gate	Counter Inputs
0.1	S13	A3-22	Q0
0.2	S13	A3-Z	Q1
0.3	S13	A2-L	Q1, Q2
0.5	S13	A2-10	Q1, Q3
1.0	S13	A2-15	Q2, Q4
2.0	S13	A2-5	Q3, Q5

The signal on the wiper of the resolution selector switch is connected to inverting gate A1-C on S15. Output from gate A1-C is reinverted by gate A1-E and serves as the reset for counter S10. Pins 4, 8, 12, 16, L, R, V, and Z the reset lines for S10 are connected to S15 Pin E causing the counter to reset with each output.

Data Control Logic

The inverted resolution selector output at S15 Pin C is also connected to the input of a monostable multivibrator at S24 Pin F. The purpose of this monostable is to provide sufficient pulse width, amplitude and drive capability to start the data acquisition cycle. Figure 4.3.4.1 shows the data control monostable schematic and drawing 596-722-031 may be referred to for a schematic and component layout of this GD/C designed circuit. The data control monostable utilizes the integrated circuit MC851 at the left in the drawing. Two other monostables (at the center and at the right in the drawing) are used by the direction sensing logic.

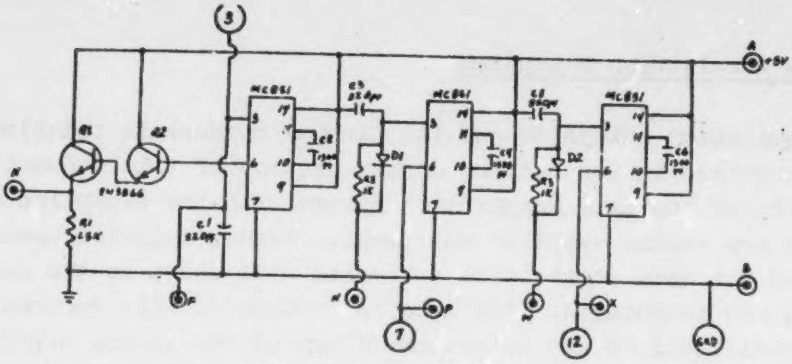


Figure 4.3.4.1 Data Control Monostable

Output of the monostable is a pulse 4.5 microseconds wide and 4 volts in amplitude at S24 Pin H. Reference to the drawing shows that the actual output at Pin H is from a Darlington amplifier. The requirement that the data coupler input be terminated by 50 ohms necessitated the Darlington amplifier on the monostable output. S24 Pin H is connected to the data control BNC connector on the control panel and from there drives the start command input to the data coupler. Figure 4.3.4.2 is an interconnection diagram of the data control logic to the system.

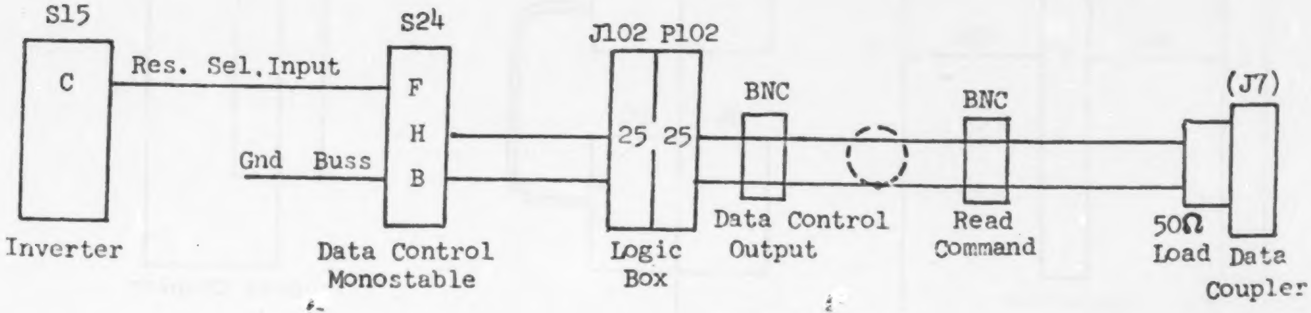


Figure 4.3.4.2. Interconnection of Data Control

The wiring table provided with this document also contains this information and may be used for interconnection of cabling during set-up.

4.3.5 Data Acquisition Subsystem

The data acquisition subsystem and its various components relationship to the system is explained in the systems design section of this document. All of the components of the data acquisition system with the exception of the analog ratio module are vendor supplied equipment. Vendor supplied manuals for the components of the data acquisition subsystem will serve as the source of details on these components. The details section of this document will be limited to modifications and interconnections of the vendor supplied components and a complete description of the ratio module.

Wavenumber Conversion (Bi-directional Counter)

Conversion of the output of the wavenumber logic to wavenumber and then to a BCD format is done by an Anadex Bi-directional Counter. Part number for the counter is CB600R W/BZ, BL, G-4A, A. CB600R is the basic part number. W/ means with the following options: BZ preset zero capability, BL preset count level, G-4A BCD printer output and A which is storage of count to enable "read-out on the fly". Option A for this instrument was implemented after delivery and is not reflected in the instrument manual title, but is included in the text. The modification to the counter involved in this late change included the factory addition of Option A and the addition of a control line to provide a hold signal to Pin 9 of J6 anytime the data acquisition system was busy. The hold signal is generated in the data coupler. Interconnection of the counter to the system is shown in Figure 4.3.5.1.

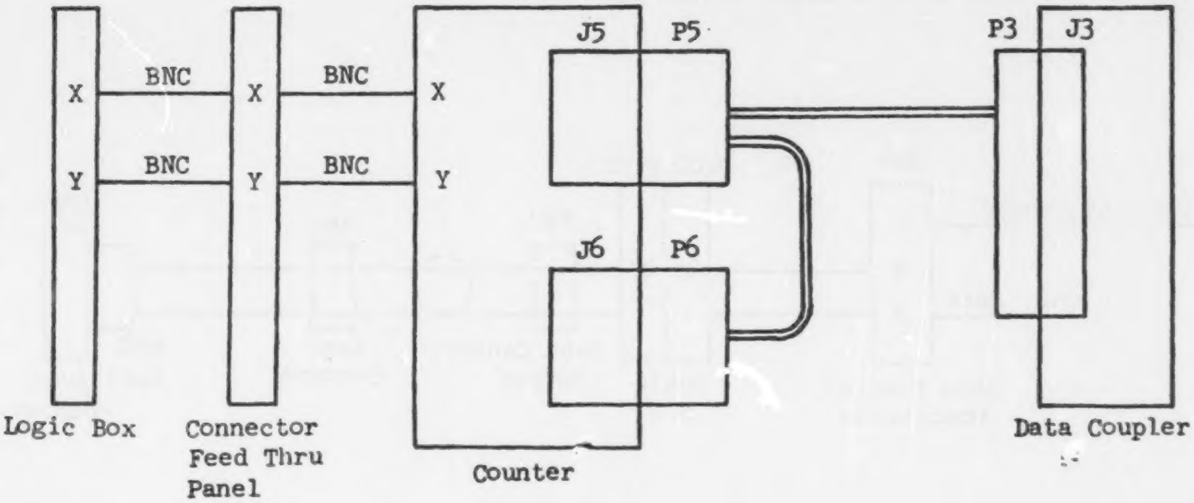


Figure 4.3.5.1. Bi-Directional Counter Interconnections

Source Digital Output Conversion (DVM 5403-015)

Conversion of the source compensation amplifier output from an analog voltage of zero to 10 VDC to a BCD format suitable for printing and recording on digital tape is done by a Dana Model 5403-015 DVM. This particular DVM has a high speed sample hold plug-in Model 015 for its front end. This enables the voltage reading to correlate exactly in time with the corresponding wavenumber. The sole modification of this DVM is the method used to input the read command. Ordinarily the read input would be at the banana jacks on the front panel. However, it was useful in this system to have a gate in the data-coupler provide the read command, and it is connected into the DVM with the rest of the control functions through P204. In effect the front panel banana jacks are now in parallel with Pins 11 and 13 on rear connector J204. Two additional wires in the output cable carry these lines to Pins 48 and 49 on J1 of the data coupler. In turn, Pins 48 and 49 are connected through an emitter follower and A5-4 to gate A5 Pin 12. This is the inverted data control signal "anded" with the hold signal from A1-4 via A1-34. The effect is to inhibit a read command to the DVM while the data acquisition system is still putting out the previous data. The changes are documented in the data coupler manual. Figure 4.3.5.2 gives the interconnections of the sample hold DVM to the system.

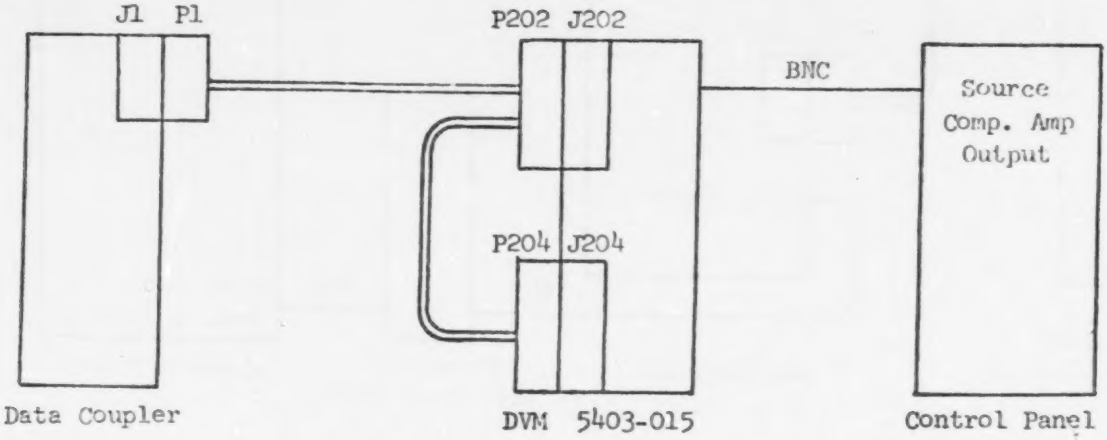


Figure 4.3.5.2 Sample Hold DVM 5403-015 Interconnections

Transmission Coefficient (τ)-Digital Output Conversion (DVM 5403-010)

Transmission coefficient in a digital form is provided by a Dana Model 5403-010 DVM. This DVM is a 5403 type with a -010 ratio input module. The input signals are the source and reference compensation amplifier outputs. The source compensation amplifier is connected to the input on the front panel. Reference compensation amplifier output is connected to the DVM reference input on the rear panel. The DVM is operated in the 10 times ratio mode resulting in an output that is 10 times the transmission coefficient. No modifications have been made to this instrument, therefore the manuals provided by Dana are completely correct. The interconnection of this DVM to the system are shown in Figure 4.3.5.3.

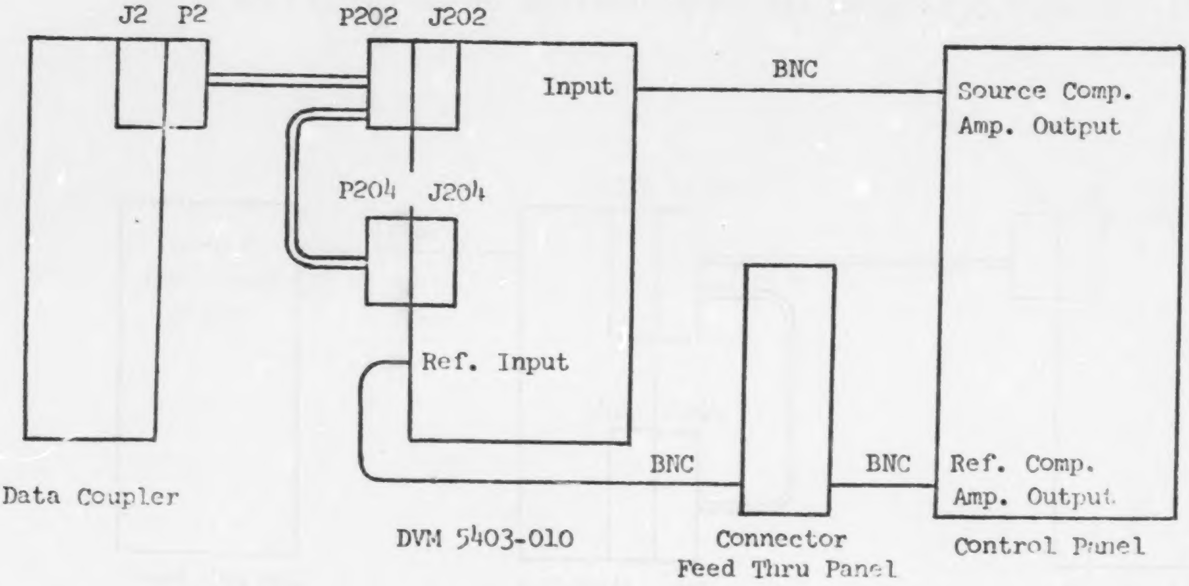


Figure 4.3.5.3. Ratio DVM 5403-010 Interconnections

Analog Ratio Module

A strip chart presentation of the transmission coefficient requires an analog signal representation of (τ). This signal is generated by the analog ratio module. Inputs to the ratio module are the source and reference compensation amplifier outputs. The output of the ratio module goes to one position of the strip chart input selector switch. From here (τ), source, or reference may be selected for display on the strip chart. Figure 4.3.5.4 is a schematic of the ratio module referenced in the discussion. Drawing 596-722-030 gives a schematic as well as component layout of the ratio module.

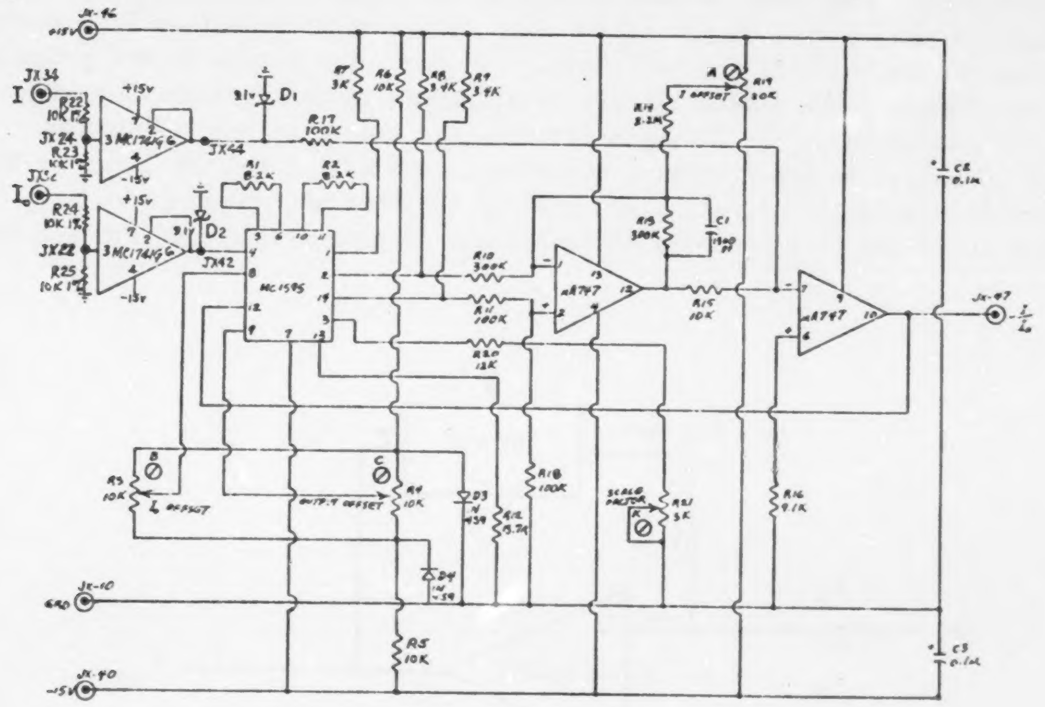


Figure 4.3.5.4. I/I$_0$ Ratio Module

Central to the ratio module is the integrated circuit MC1595 which is a Motorola linear multiplier. The circuit is simular to one recommended by Motorola to produce a division of input signals. Exceptions to the circuit recommended in Motorola application notes were made to improve the performance. Zener diodes D1 and D2 were placed across the input to protect the circuit from excessive input signal. Diodes D3 and D4 were inserted in place of resistors. The network R3, R4, R5, R6, D3 and D4 is the input offset adjustment network. The use of the diodes made possible a finer adjustment of the offset. Dual operational amplifier μA747 was used instead of the recommended Motorola operational amplifier to save components. Both amplifiers are similar but the μA747 does not require external compensation and is used for this reason. A detailed description of circuit operation is given in Motorola application note AN-490. A brief description is given here to convey a general understanding. The MC1595 integrated circuit consists primarily of three differential amplifiers. There are two differential amplifiers for the input amplifiers, Pin 4(+) and 8(-) are the inputs to one and 9(+) and 12(-) are the other inputs. The third differential amplifier serves as the load for the amplifier with Pins 9 and 12 inputs. The load differential amplifier is base driven by the input differential amplifier with inputs 4 and 8. The output of the load differential amplifier is therefore a function of the two differential inputs. In fact, the output is the product of the two inputs. The divide circuit is simply an inverting amplifier with the product function in the feedback circuit. In this case the (1/2)μ A747 with Pin 10 output is the inverting amplifier. The MC1595 and the other (1/2)μ A747 form the product of I_o and I and make up the feedback component of the inverting amplifier. Figure 4.3.5.5 is a block diagram of the I/I_o ratio module.

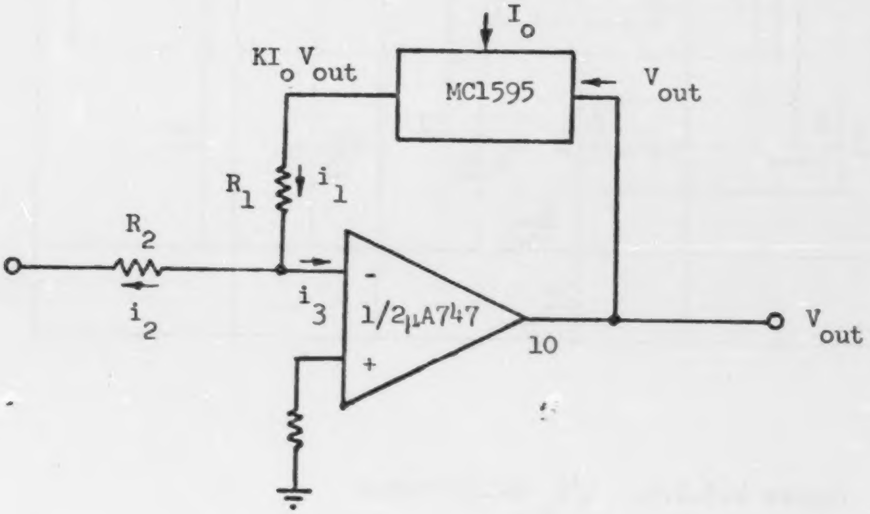


Figure 4.3.5.5. I/I_o Block Diagram

From this simplified drawing it is easier to see the divider as a simple inverting amplifier. The virtual ground at the (-) input makes the current i_1 and i_2 equal to

$$i_1 = \frac{KI_o V_{out}}{R_1}$$

$$i_2 = \frac{-I}{R_2}$$

Assuming the bias current i_3 equals zero and solving for V_{out} yields

$$V_{out} = \frac{-IR_1}{I_o KR_2}$$

If $R_1 = KR_2$

$$V_{out} = -I/I_o$$

The divider circuit used has R_2 equal to 100K and R_1 equal to 10K. K which is adjustable is set for 1/10 generating the proper value of V_{out}. There are four adjustments associated with this circuit. They are I_o offset (R_3), I offset (R_{19}), output offset (R_4) and the scale factor K(R_{21}). The adjustment procedure should not be required under normal conditions but is given here for reference.

I/I_o Adjustment Procedure

1. Set I = 0
2. Adjust R_{19} for I/I_o = Constant for any I_o
3. Adjust R_4 for I/I_o = 0V
4. Set I = I_o
5. Adjust R_3 for I/I_o = Constant for any $I = I_o$
6. Adjust R_{21} for I/I_o = 1.00V

Interconnection of the I/I_o ratio module and the recorder input switch to the system is illustrated in Figure 4.3.5.6.

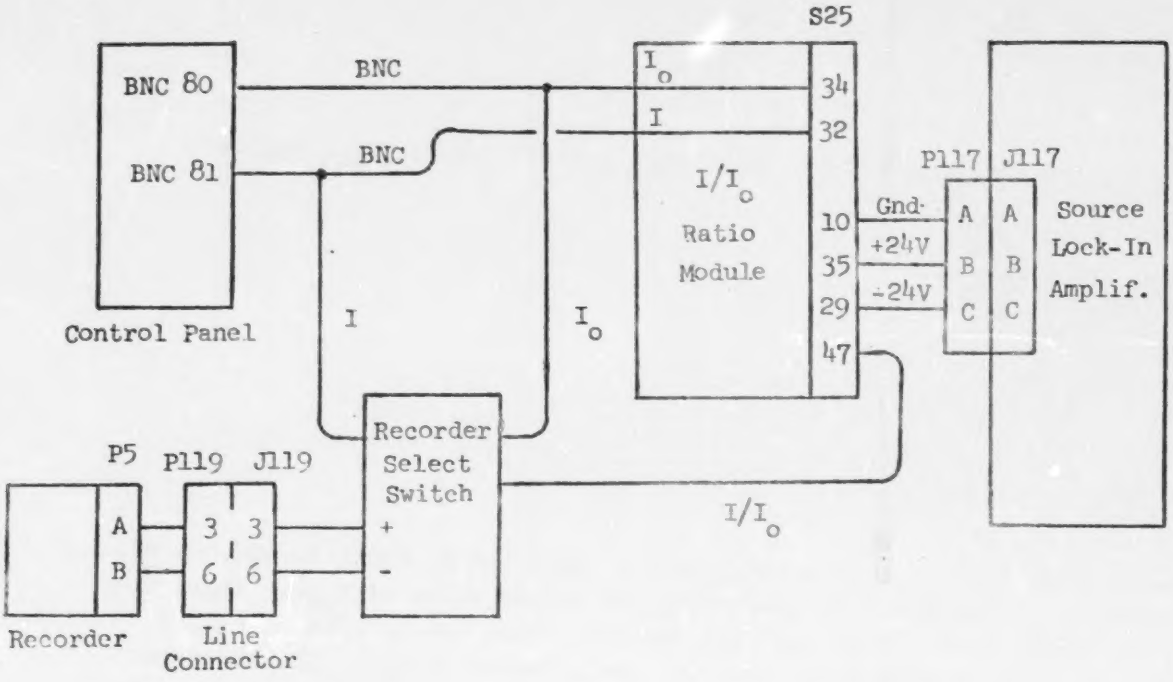


Figure 4.3.5.6. I/I_o and Recorder Select Switch Interconnections

Digital Data Coupler

The purpose of the data coupler is to format the 13 BCD characters outputted by the counter and DVMs and, on command, cause them to be recorded on the digital printer and/or the digital tape recorder. A Zentel Model 649 coupler is used in this system. The manual provided by Zentel has a number of errors and GD/C has modified the instrument to a limited degree. Overall interaction of this instrument with the system is described in the design section. This section discusses the modifications, physical interconnection of the coupler and the errors in the manual. Manual errors are listed here in the sequence they appear in the manual.

1. Page 4 - First Sentence - this input must be driven from a low impedance source as a 50 ohm termination is required at this input.

2. Drawing No. 9706-02 XFR, MODE & RS CLK labels at input to shift registers in wrong place; corrected drawing.

   Output of DG-3 is pin 22 not 23.

   Operate and Standby labels reversed on S3.

3. Drawing No. 9076-04; 2 of 2. P6 Pin 9 called follow is really the counter hold line.

4. Drawing No. 9076-05; 2 of 2 - Pins 48 and 49 of P1 are the hold command to the sample hold DVM 5403-015.

5. P2 of the coupler is the input connector from DVM 5403-010. No drawing is given for this cable, however it is a duplicate of P1 except Pins 48 and 49 are not connected.

Modifications to the coupler system are pencil sketched on Drawing 9076-02. The manual start input circuit has been changed from a direct switch to ground at A4-26 to a switch to +5 volts that is inverted by gate A7-8. This avoids contact bounce double triggering the Start Flip-Flop. The remote start which is the data control input originally was inverted by gate A5-12 and inputted to the Start Flip-Flop. A modification "ANDS" the hold signal through delay generator, DG4, with the remote start at gate A5-12. The purpose of this change was to inhibit a second start or data control pulse while the data coupler is still executing the previous command. The third modification to the coupler provided a method of generating a hold command to the bi-directional counter. Gates A1-4, A1-8, A5-9, and A5-33 are used in this modification. The output is "1" between the receipt of a start command and the completion of execution of a data recording sequence.

Gate A1-4 inverts this "0" and provides a "1" to Pin 9 of P6 on the counter which holds the counter output during the recording sequence. Use of the pencil corrected schematic diagram Drawing 9076-02 and the timing sequence, Figure 2 of the Coupler Manual, can be made to justify these statements.

Figure 4,3.5.7 is an interconnecting diagram for the coupler to the system.

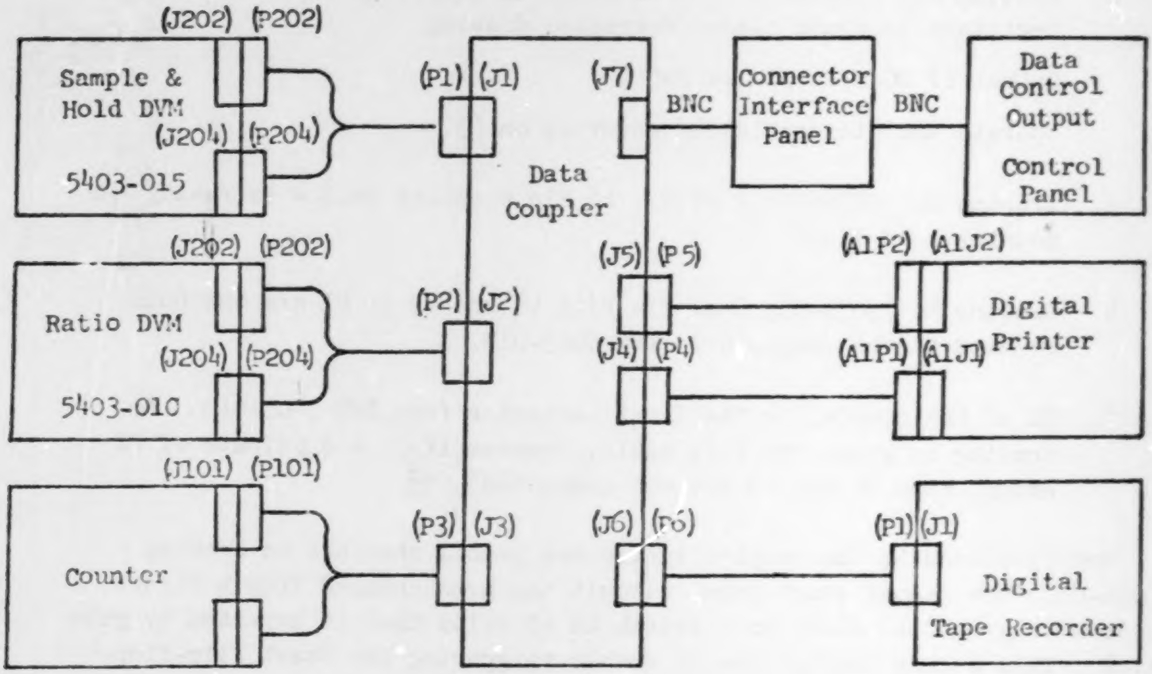


Figure 4.3.5.7. Data Coupler Interconnections

The cables for (P1), (P2), (P3) and (P7) are described in the coupler manual.

The cables for (P4) and (P5) are 50 wire (pin for pin) cables supplied with the digital printer.

Automatic Marker-Analog Recorder

It is operationally convenient to have an automated marker system to place wavenumber marks at the edge of the analog record. This allows the operator to concentrate on more important aspects of the run.

The automatic markers system is driven by the decade units of the bi-direction counter. Each counter decade has a previously unused output $\overline{\text{ZERO}}$ which goes low when the decade reads zero (pin 26). A ground connection and pin 26 of the three least significant decades were brought out to J118 on the back of the counter.

The counter information is conducted to the marker selector box located just to the left of the analog recorder. There it is applied to simple logic to produce a high output whenever the counter reads even units, tens or hundreds of wavenumbers. Since the logic units cannot drive the marker directly, a driver consisting of two emitter followers and an SCR are used. A capacitor on the output of the first emitter follower provides pulse stretching required at the highest scan speed.

Power for the logic and driver is derived from +24 volts from the NIM BIN via J120 by means of a zener diode.

Output of the marker selector goes to the right marker jack at the rear of the analog recorder.

Provision is made for selection of automatic, manual or no marker. Manual marker input is on the front panel at the left of the analog recorder.

The automatic marker is shown on drawing 596-722-035 and in Figure 4.3.5.8.

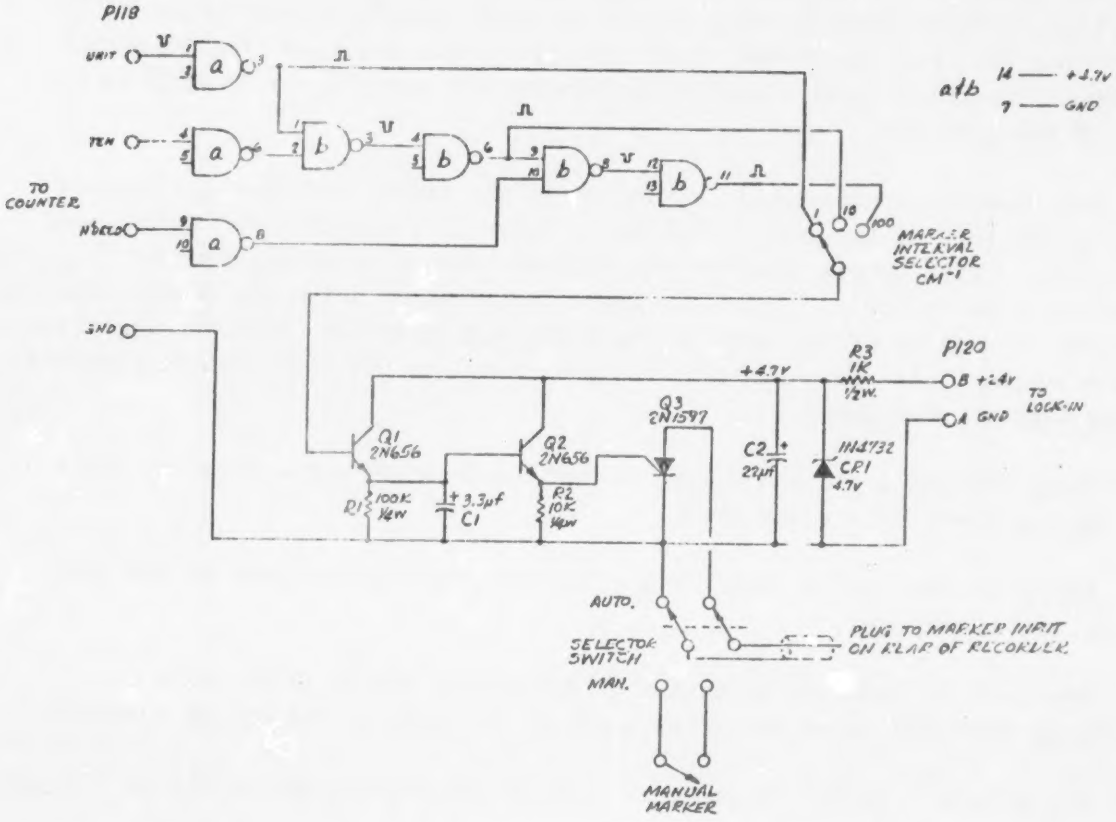


Figure 4.3.5.8 Marker Control

4.3.6 Data Recording Subsystem

The data recording subsystem consists of a strip chart recorder HP7701A with its associated preamplifier HP8801A as an analog recorder, and two digital recorders, a HP5050B digital line printer and a Kennedy 1600H digital incremental tape recorder. The system design section discusses their operation in this system. Manuals have been provided by the manufacturer on each of these items. No modifications have been made to any of this vendor equipment and hence, the manuals can be directly referred to for detail information. The interconnection of the digital recorders is shown in Figure 4.3.5.7, the data coupler interconnection diagram. An interconnection diagram for the strip chart recorder is shown in Figure 4.3.6.1.

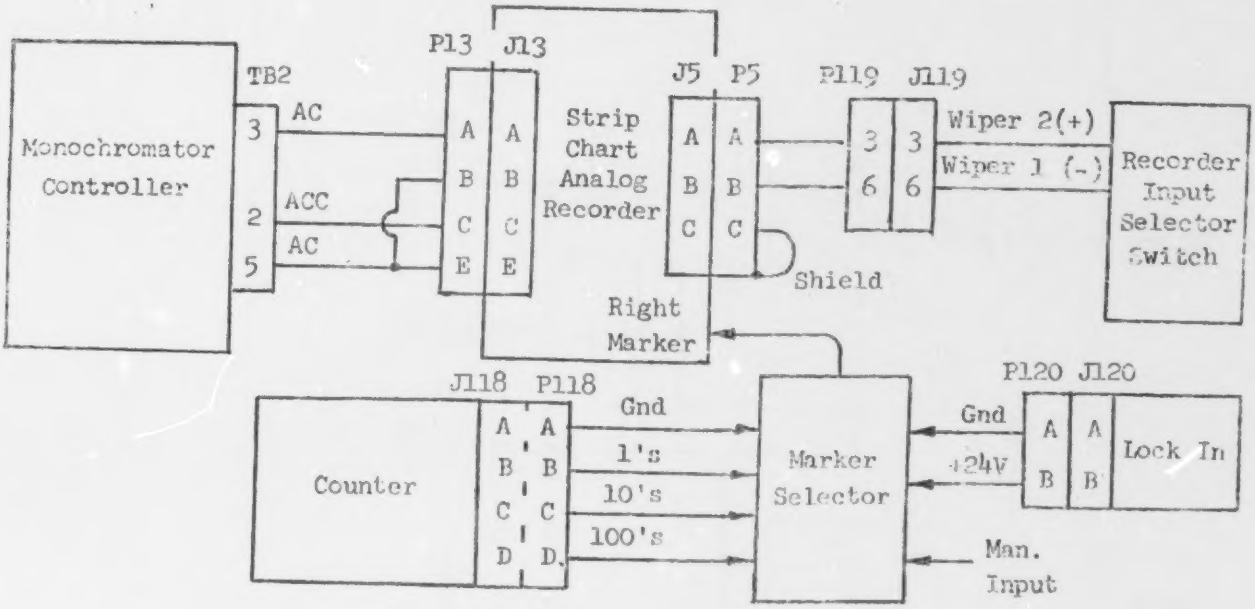


Figure 4.3.6.1. Strip Chart Recorder Interconnections

The strip chart motor may be run remotely. Normal operation of the ROSE system has the strip chart in the REMOTE run mode. When the λ DRIVE switch on the monochromator controller is turned on, both the monochromator and strip chart drive motors are started. When the CHART switch on the monochromator controller is turned on, the strip chart drive motor will run (if the recorder is in REMOTE) but the wavenumber drive motor will not run.

4.3.7 Electronics Calibration

Standardized signals are provided to enable a check of amplifier response and data acquisition system accuracy. When the STD SIGNAL-OPERATE switch is in the STD SIGNAL position a voltage of known amplitude is inserted into the selective amplifiers. The ratio of the voltage inserted in the source selective amplifier to the voltage inserted into the reference selective amplifier may be controlled by a control panel potentiometer labled "Standard Signal (τ) Adjust".

Standard Signal Generators

A circuit called standard signal generator located at S20 of the logic box generates the standard signal. Figure 4.3.7.1 is a schematic of the standard signal generator.

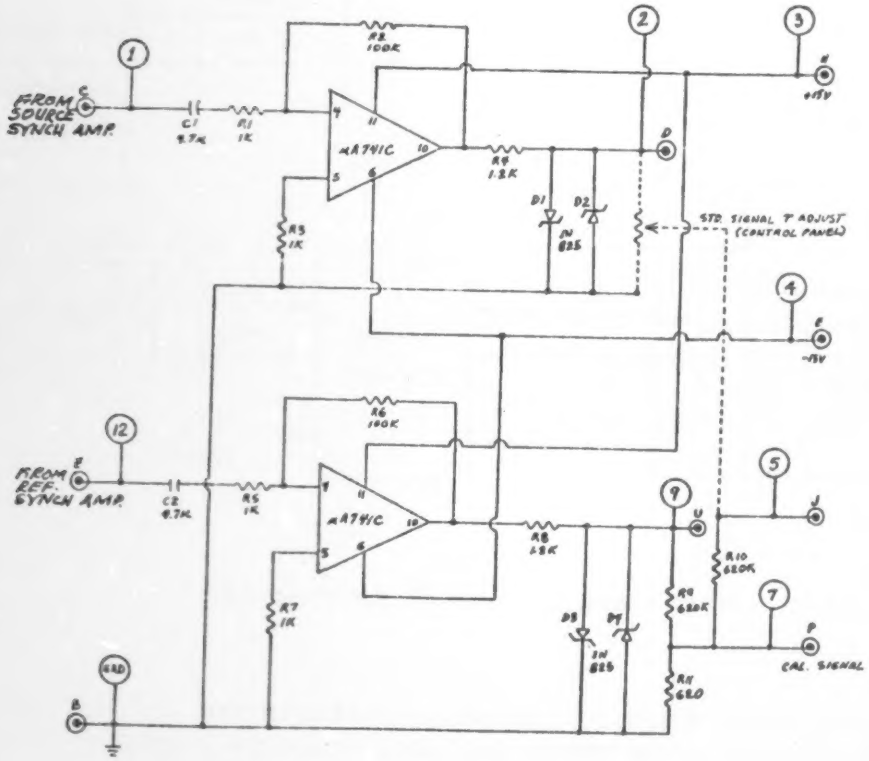


Figure 4.3.7.1. Standard Signal Generator

Drawing 596-722-025 contains both a schematic and a component layout of the standard signal generator. This circuit takes advantage of the fact that the output of the synch amplifiers is a signal which is frequency locked to the source and reference choppers. Use of this signal as an input to the standard signal generator ensures a calibration output signal at the chopper frequencies. Both circuits are identical with the exception that their outputs are mixed together differently. The amplifiers take an input signal that is generally a ±15 volt square wave and attempt to provide a gain of 100. Output will then be ±15 volt square waves at Pin 10 even if the synch amplifiers are not saturated. Diodes D1, D2, D3, and D4 are 6.4 volt Zener reference diodes each of which has an opposing diode in series with the Zener element. The output to the resistor network is a ±6.4 volt square wave independent of input signal condition and amplifier characteristics. Voltage divider R9, R10, R11 results in a 1000 to 1 division of its input voltages at S20 Pin U and S20 Pin J appearing at S20 Pin P. If the STD. Signal (τ) Adjust potentiometer is set nearest Pin D, equivalent to (τ) equals 1.0,both inputs at Pins U and J are 6.4 volts. The output called "Cal Signal" is then a mixed signal of 6.4 mv of each of the chopper frequencies. Since the (τ) adjust potentiometer is connected to the source standard signal it controls the percentage of source signal mixed. This is equivalent to it being a linear control of (τ) provided by the standard signal generator. The wiring table presents clear and concise interconnection information for this circuit which is completely hard wired.

4.3.8 Power Subsystem

The 115V 60 Hz input power to the instrument is converted internally to D.C. voltage, blackbody heater currents and chopper drive voltages. Again, detailed information is contained here on the GD/C designs and references to vendor manuals are made on vendor equipment.

D.C. Voltages

D.C. voltage requirements are ±24, ±15, ±6 and +5. The ±24 VDC is supplied by the PAR Model 200 NIM BIN. Its primary purpose is to supply the PAR amplifiers plugged into it with ±24 VDC. However, it was decided to have the PAR preamplifier located remotely near the detector. The ±24 VDC from the NIM BIN was cabled to the receiver assembly stand for the preamplifier. The +24 VDC available at the receiver assembly stand was also utilized for detector bias, gyrator and source synch preamplifier supply voltage. Interconnection of the ±24 volt supply in the system is shown in Figure 4.3.8.1.

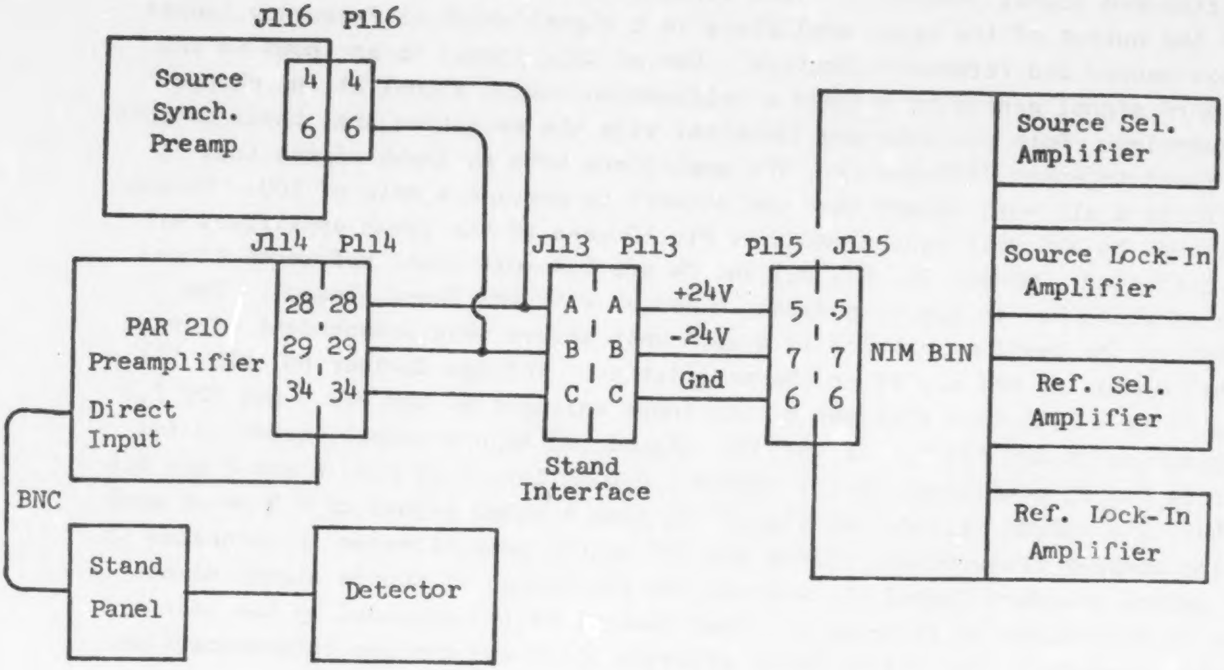


Figure 4.3.8.1. ±24 VDC Interconnections

The bias to the detector is simply a 10K ohm resistor tied through a low pass filter to the ±24 VDC fed through the input cable.

A Data Technology Model 597 modular power supply is used to provide ±15V and +5 volts D.C. This multiple output power supply is located in the logic box. The predominate usage of ±15 VDC is by the I.C. amplifiers used in such circuits as the synch, compensation and voltage follower amplifiers and the standard signal generators. All of these circuits are in the logic box. Digital integrated circuits use +5 VDC; the power supply and the circuits which use this voltage are located together in the logic box. Complete information on this power supply is contained in the Data Technology specification manual. Circuits providing ±6 VDC located in the logic box at S16 and S17 are used primarily as the supplies for the encoder. They are however also used to supply bias for the LED and diode detector associated with the generation of the reference synch signal. Figure 4.3.8.2 is a schematic of the ±6V power supplies. Drawing 596-722-028 contains this schematic and a component layout for the ±6 VDC supplies. The two supplies have closely corresponding test points and pin numbers with the positive supply being at S16 and the negative at S17.

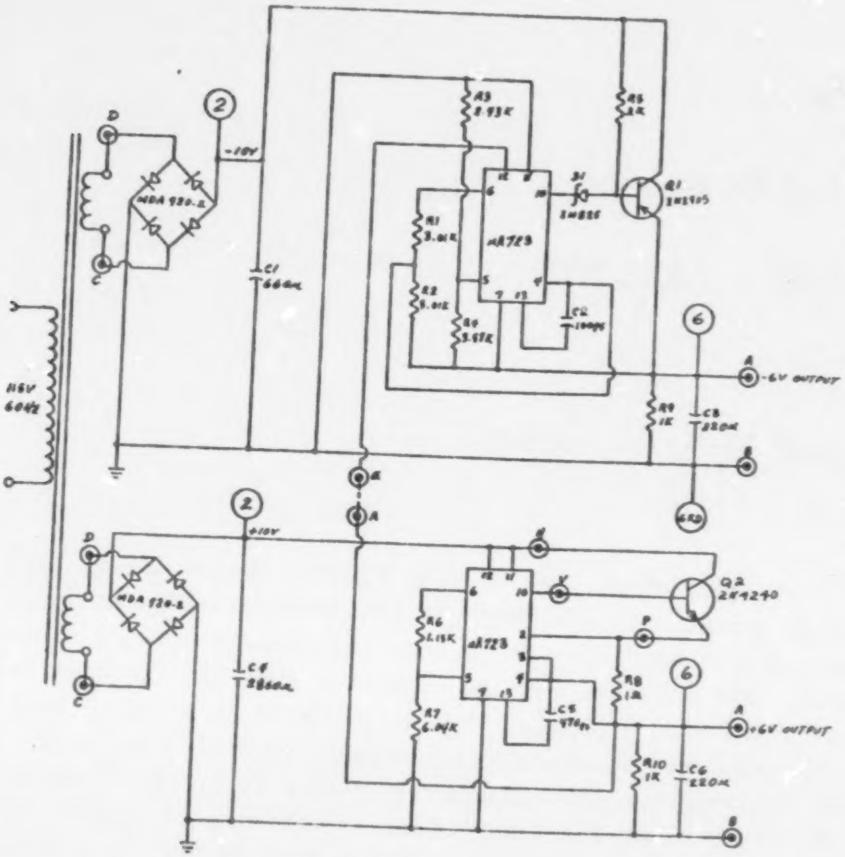


Figure 4.3.8.2. ±6 Volt Power Supplies

Both power supplies are similar in that they both utilize a 10 volt secondary of a transformer for the unregulated input and a Fairchild µA723 as the regulator. The negative regulator is a standard configuration for the use of a µA723 as a negative regulator. Output voltage from this configuration is determined from the formula

$$V_{out} = \frac{-V_{ref}}{2} \times \frac{R_3 + R_x}{R_4}$$

where

$$R_1 = R_2$$

$$V_{ref} = 7.15 \text{ VDC nominal}$$

$$V_{out} = \frac{7.15}{2} \times \frac{2.43 + 3.57}{3.57}$$

$$= 3.57 \times \frac{6}{3.57} = -6 \text{ VDC}$$

Diode D1 is a 6 volt Zener diode used to make Pin 10, the output of the regulator, run near ground. Q1 a 2N2905 PNP transistor acts as the pass transistor in this series regulator minimizing the current drained directly from the regulator. The positive voltage regulator must provide significantly more current than the negative supply. For this reason C4 is much larger than C1. Also, the high output current requirement is reflected in the use of the 2N4240 for the external pass transistor. This is a power transistor located on a heat sink next to the transformer. Resistors R6 and R7 are the output voltage determining components where the output voltage is determined by

$$V_{out} = V_{ref} \times \frac{R7}{R6 + R7}$$

$$= 7.15 \times \frac{6.04K}{6.04K + 1.15K} = 7.15 \times \frac{6.04}{7.19}$$

$$V_{out} = +6 \text{ VDC}$$

Resistor R8 is a current limiting resistor. When the voltage across R8 reaches 0.6 VDC it turns on a currenting limiting transistor inside the I.C. and removes the drive to the pass transistor. In this case R8 limits the output current to 600 ma. Interconnection of the ±6 VDC to the encoder and synch pulse generator is sufficiently clear in the wiring tables. To trace the interconnections start with S16 and S17 Pin A for the +6V and -6V respectively.

Chopper Drive

The source chopper is an Electro-Optical Industries Model 311 mounted on the source blackbody. The control unit that allows for selection of the chopper frequency is located in the source auxiliary stand. The relationship of the chopper to the system and its justification are covered in the system design section. A vendor manual on the Model 311 is provided and sufficiently covers the chopper and its drive circuitry.

The reference chopper and its associated drive circuitry are a GD/C design. Mechanical and optical considerations are covered in their respective sections as this component is predominantly mechanical and optical in nature. This section describes the drive circuitry and interconnection of the reference chopper. The reference chopper motor (Globe Industries 83A/008) requires 115 VAC, 400 Hz and 40 watts nominal. Since the motor is an A.C. hyteresis synchronous type its running speed is set by the drive frequency. Nominal frequency used in this system is 440 Hz which yields a chopping frequency of 330 Hz. This frequency is adjustable over a minimum ±10% of the center frequency. This ensures that the operating frequency will not be a harmonic of either 60 Hz or the source chopping frequency. Figure 4.3.8.3 is a schematic diagram of the circuit called the chopper motor drive. This circuit is in a chassis located in a portion of the strip chart recorder rack not used by the recorder. The reference chopper drive is shown on drawing 596-722-029.

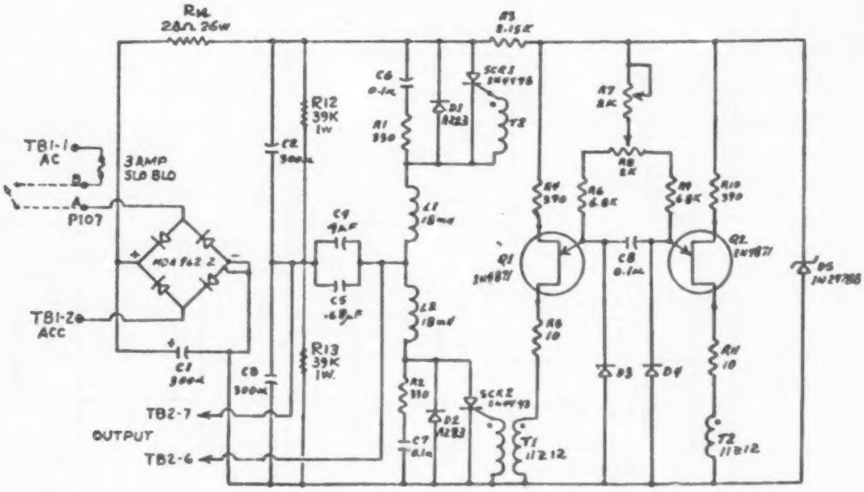


Figure 4.3.8.3. Reference Chopper Motor Drive

Input power to circuit is 115V 60 Hz. It is rectified by a modular full wave bridge Motorola MDA-962-Z and capacitor C1.

Output of the bridge is 165 VDC. The A.C. input is controlled by the reference oscillator on-off switch located on the control panel. When the switch is in the "on" position the D.C. supply voltage is divided by capacitors C2 and C3 and can be looked at like a ±supply for the power amplifier portion of the circuit. D.C. input voltage is also zenered to +14 VDC by diode D5 and resistor R3. Fourteen volts then becomes the supply voltage for the oscillator portion of the circuit. Q1 and Q2 are 2N4871 unijunctions serving as the active components in a unijunction relaxation oscillator. Frequency determining components are C8, R6, R9 and R7. Frequency adjustment is made by the 2K ohm potentiometer R7. Diodes D3 and D4 serve as flyback diodes to prevent damage to the 2N4871 unijunction. Transformers T1 and T2 (Sprague 11Z12) couple a pulse form of the oscillator output to the gates of SCR1 and SCR2. Capacitor C5 with either L1 or L2 is a series resonant circuit. The result of alternately switching the opposing voltage on C2 and C3 into the resonant circuit is a sinusoidal output of 115 VAC at the oscillator frequency. Diodes D1 and D2 in parallel with the SCRs are to prevent the resonant circuit from presenting large reverse voltages across the SCRs. Network R1, C6 or R2 C7 aid the turn on characteristics of the SCR's. Experience with this circuit indicates that if something causes the circuit to fail the 2N4443 SCRs will invariably short anode to cathode. Thus they should be checked first in a trouble shooting procedure.

Figure 4.3.8.4 is an interconnection diagram of the reference chopper drive circuit.

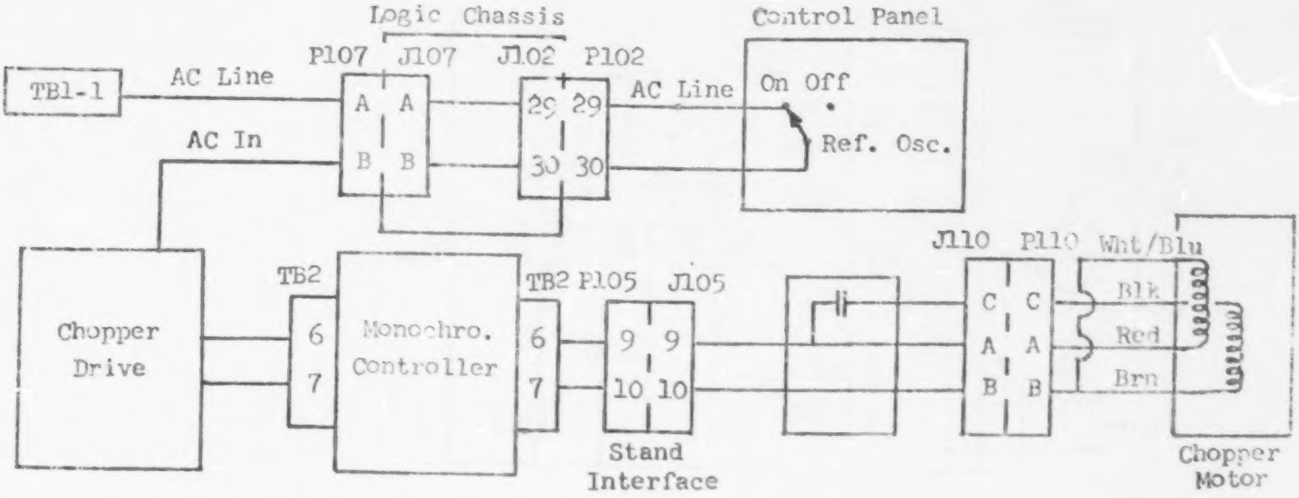


Figure 4.3.8.4. Chopper Motor Drive Interconnections

Blackbody Heaters

The two blackbody controllers are identical Electro-Optical Industries Model 216A temperature controllers. Their basic principle of operation is explained in the design section and their details are adequately covered by the vendor supplied manuals. Therefore, further discussion is not necessary in this section.

5.0 SYSTEM OPERATION

In this section information relating to system operation is given which includes preliminary calibration, system installation, starting the system, test parameter selection, procedure, and system shut-down.

Prior to operation, the equipment manuals should be read carefully. The instructions here are intended to augment those of the manuals particularly for conditions which are unique for the ROSE system.

5.1 PRELIMINARY CALIBRATIONS

There are a number of preliminary calibrations which should be made. Most will need to be made infrequently as indicated in the following sections.

5.1.1 Blackbody Calibration

After each rebuilding of either blackbody, or at other times if there is sufficient reason, it will be necessary to determine the control settings which will produce a match of the source and reference blackbody temperatures. An opitcal pyrometer is almost essential to this operation (although the radiometer probe could also be used it does not give a direct temperature readout but only indicates equality of radiance). The procedure given in Section 4.1.1 should be followed.

5.1.2 Electronic Calibration

It is assumed that checkout of the electronic components recommended by the manufacturers in the instrument manuals will be carried out as required. Beyond these checkouts it may be desirable, from time to time, to check particularily the system gain.

A 18 millivolt peak-to-peak square wave calibrating signal is available at the lock in amplifier REFERENCE IN/OUT connector when the reference switch is in the CAL position. In the ROSE system a calibration in terms of lock-in amplifier D.C. volts out per rms volts input is desired. This kind of calibration is described in the lock-in amplifier manual; the calibration is applied to the INPUT of a selective amplifier whose RESONANCE OUTPUT is connected to the INPUT of the lock-in amplifier. For the original lock-in instrumentation the least sensitive 10 mv range was used (sensitivity ranges are 1, 25 and 10 mv) and, with a Model 210 selective amplifier gain of 1.0, the lock-in meter is set to 0.81 of full scale by means of the GAIN ADJ. on the lock-in amplifier front panel. The ratio of the peak to peak voltage of a square wave to the rms voltage of the fundamental is 2.22 so that the rms fundamental output voltage of the selective amplifier in this case is 18/2.22 = 8.1 millivolts. By setting the meter to 0.81 of full scale on the 10 millivolt range the instrument MONITOR output is calibrated to read 10 volts D.C. out for 10 millivolts rms fundamental input (meter full scale equals 10 volts D.C. at the MONITOR output). This can be looked upon as a lock in amplifier gain of 1000 volts DC/volt rms from the selective amplifier INPUT to the lock in amplifier MONITOR output.

The Model 220A lock-in amplifier has been modified to have 100 times less sensitivity or gain. It is stated in the lock-in manual revision that the CAL output, therefore, cannot be used (it is still 18 mv peak to peak). However, if the 220A lock-in amplifier is placed on its most sensitive range of 100 mv and a GAIN setting of 10 is used in the selective amplifier the overall sensitivity is again 10 mv and the original procedure of applying the calibration signal to the selective amplifier INPUT and setting the meter to 0.81 of full scale as before may be used. The overall gain can be looked upon as a gain of (10 volts DC lock-in amplifier output)/(10 millivolts rms fundamental input) or an overall gain of 1000 volts DC/volt rms. With a GAIN setting of 10 in the selective amplifier in this case, this overall gain corresponds to a gain of 100 volts DC/volt rms in the lock-in amplifier in the most sensitive position. A new GAIN label on each 220A lock-in amplifier is marked 100,50,20,10 to correspond to 100,200,500, and 1000 millivolt SENSITIVITY settings of the modified lock-in amplifier. These lock-in amplifiers GAIN settings refer to the DC volts at the MONITOR output per rms volt at the lock-in amplifier INPUT.

Calibration can be extended to include the Model 213 preamplifier by using an appropriate precision voltage divider between the calibration signal at the REFERENCE IN/OUT terminal of the lock-in amplifier and the INPUT terminal of the Model 213 preamplifier.

The gain of the source voltage follower and the source compensation amplifier may be checked by using the D.C. output with ZERO SUPPR. on the lock-in amplifier as a signal source (connect the lock in MONITOR output to the SOURCE LOCK IN INPUT terminal on the control panel) and reading, by means of the DVM, the voltage there and at the SOURCE COMP. AMP OUTPUT terminal with τ SIG set at maximum (= 1,000). ZERO SUPP should not exceed .125 (= 1.25 volts) since this will give 10 volts at the source compensation amplifier output (gain = 8.0 nominal). Note that the SOURCE LOCK IN INPUT is a misnomer since that terminal is actually the source compensation amplifier input. A similar situation exists at the terminal labelled REF. LOCK IN INPUT.

The gain of the reference voltage follower and the reference compensation amplifier can be checked in a similar manner with the following exceptions. The SOURCE LOCK IN INPUT must be zero (a 5K resistor in a BNC connector at this terminal is best; shorting may upset the bias). The polarity of the ZERO SUPPR must be reversed and applied to the REF LOCK IN INPUT terminal for a positive reference compensation amplifier output. The maximum ZERO SUPPR in this case is -1.000 (= -10 volts) since the reference compensation amplifier gain to the reference signal is nominally -1.0.

Be sure to return the ZERO SUPP selector switch to OFF before attempting to use the lock-in amplifier for normal operation in the transmission mode.

5.1.3 Monochromator Calibrations

There are two types of calibrations which may be made, from time to time, as experience indicates a need for them. These are slit calibrations (of width and height) and wavenumber calibrations. Both of these have been made and the procedure and results are given in Section 4.1.4. Slit width and height calibrations will probably need to be made infrequently. Unless there is reason to suspect the wavenumber calibration, it will also need to be made infrequently.

5.2 SYSTEM INSTALLATION

System installation consists of selection of a suitable site, setting up and aligning the stands which includes making interconnections between the various components.

5.2.1 Site Selection

The selection of a site will depend on many factors so that only general guidelines can be given. Operational factors such as wind direction and background will be important in selecting a site for emission tests. Location of the path for transmission tests will be governed by the availability of sites, wind direction and the nature of the test object itself. The convenience of commercial 110V 60 Hz power should be considered along with firm footing for the stands and if possible a pleasant working environment. In almost all cases the sites will be a result of compromise betwen the above and possibly other factors.

5.2.2 Stand Set Up

If the telescopes have been removed from the stands these should first be assembled following the instructions given in Section 4.2.5.

After placing the various main assemblies roughly in position the interconnections should be made. After a few set-ups these will become routine. Intially, or after long periods, the following references will be helpful (596-722-033 is the interconnection drawing).

Blackbodies	596-722-033	and Section 4.2.4
Cryocooler	596-722-033	and Section 4.2.10
Rcvr Stand Panel	596-722-033	and Section 4.2.1
Electronic Consoles	596-722-033	and Section 4.3
Power	596-722-033	

With the connections made the stands are to be aligned.

In the emission mode of operation the objective is to point the receiver stand assembly at a given target. The wide field alignment device is placed in the holder at the monochromator entrance slit and after roughly pointing the stand assembly in the desired direction and retracting the wheels the object is brought to the center of the reticle field by successive approximations. After the first approximation the sides of the front pads should be aligned with the rear pad as shown on Figure 5.2.2.1 by sighting along the sides of the front pads. Final azimuth and elevation adjustments can be made as indicated in Section 4.2.1.

In the transmission mode of operation the objective is to point the telescopes at one another. First, the stands should be roughly aligned by eye. Then, using the wide field eyepieces, the azimuth and elevation adjustments should be made by successive approximations to bring the image of the remote telescope onto the center cross lines of the eyepiece reticle. The front pads should be aligned as shown in Figure 5.2.2.1 Final azimuth and elevation adjustments can be made as indicated in Section 4.2.1 using the microscope alignment device.

Note that the field of view in the wide field alignment device is inverted relative to that in the microscope alignment devices.

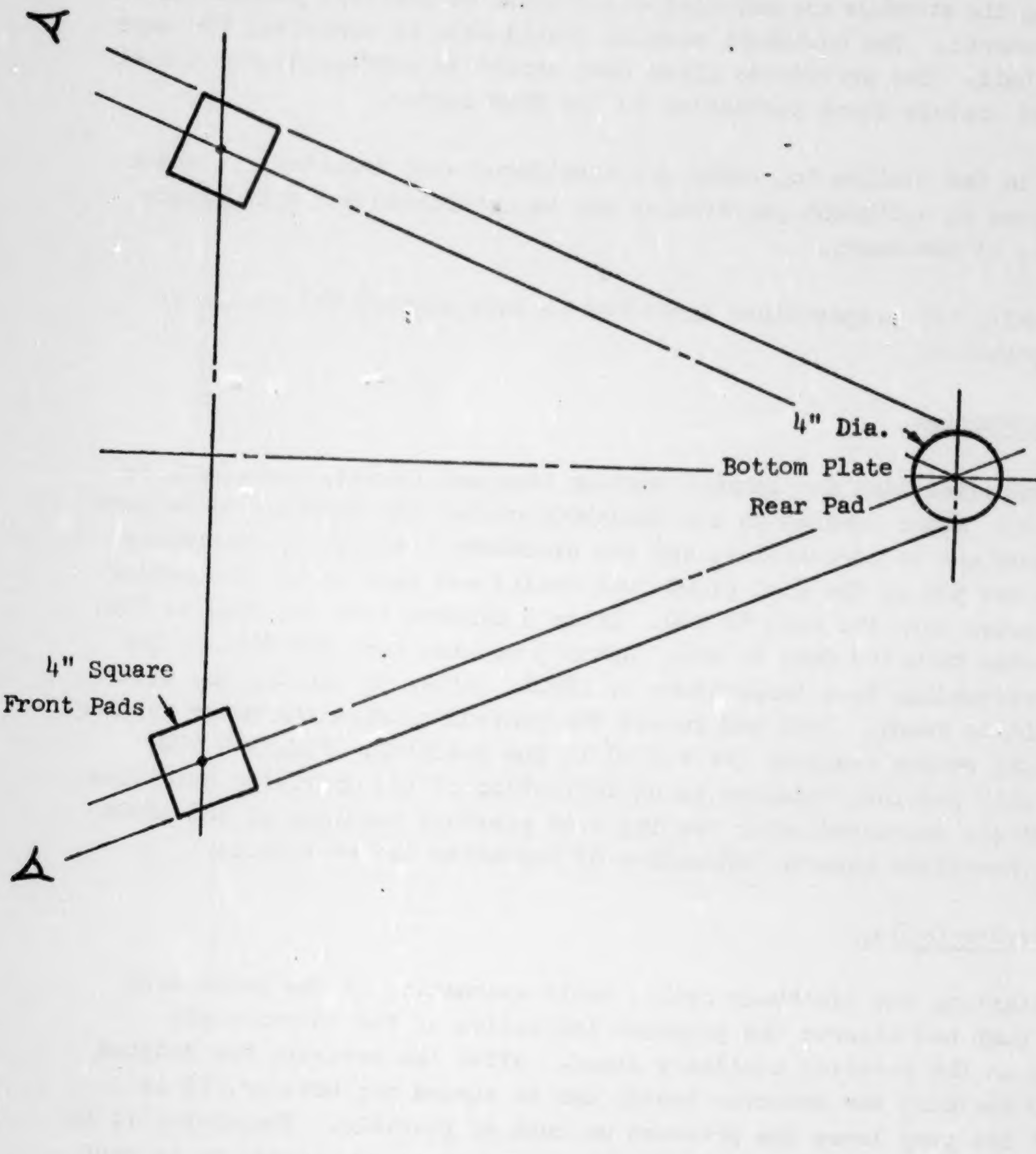


Figure 5.2.2.1 Stand Pad Alignment

5.3 STARTING THE SYSTEM

After setting up the system and making the interconnections as described in Section 5.2, the next step is to start up the system. There is a preferred order based mainly on the equipment warm up times. A typical starting schedule as shown on Figure 5.3.1 which is intended as a guide. Experience may indicate desirable modifications of this schedule.

Following the schedule are detailed discussions of starting procedures for several components. The equipment manuals should also be consulted for more component detail. The procedures given here should be sufficient for normal operation and include those particular to the ROSE system.

Entries in the various log books are considered very important in order that variations in equipment performance may be determined and appropriate action taken, if necessary.

After making the preparations described in this section the system is ready for operation.

5.3.1. Blackbodies

The blackbodies have the longest warm-up time and should, therefore, be started first. After turning on the blackbody cooler and checking to be sure the glycol coolant is circulating, set the blackbody temperature controller to HI range and 500 on the dial (1000 full scale) and turn on the controller. After 90 minutes turn the dail to 600. After 5 minutes turn the dial to 800. After 5 minutes turn the dial to 900. After 5 minutes turn the dial to the setting corresponding to a temperature of 1800K. After 90 minutes the blackbodies should be ready. Note and record the controller dial and meter readings and the cavity sensor readings (on a DVM) in the BLACKBODY OPERATING LOG. Comparison with previous readings is an indication of the operating condition. A progressively increased meter reading over previous readings at the 1800K setting has sometimes been an indication of impending heater burnout.

5.3.2 Detector Cooler

After starting the blackbody cycle, begin evacuation of the Dewar with the vacuum pump and observe the pressure indication of the thermocouple vacuum gage on the receiver auxiliary stand. After the pressure has dropped to below 50 microns, the detector cooler can be turned on; however, it is best to let the pump lower the pressure as much as possible. Therefore, it is recommended that the detector cooler be turned on about 30 minutes to an hour before the cooled detector is actually needed. Note the time, the reading of the detector cooler suction pressure and oil level (before and after turn-on) in the DETECTOR COOLER OPERATING LOG.

Time	Item
t - 195 min.	Blackbody Start (Dial 500)(cold start only)
t - 150	Start Dewar Evacuation
t - 105	Blackbody Dial = 600
t - 100	Blackbody Dial = 800
t - 95	Blackbody Dial = 900
t - 90	Blackbody Dial = (Setting for 1800K)
t - 60	Source Chopper On (transmission only)
t - 60	Reference Chopper On
t - 30	Detector Cooler On
t - 30	Electronic Power On
t - 20	Dewar Vacuum Valve Closed (if $P < 50\mu$)
t - 15	Detector Cooler Temperature Set
t - 0	System Ready for Operation

Figure 5.3.1 Typical Starting Schedule

Usually the first indication of cooling is a drop in the thermocouple vacuum gage pressure reading which indicates cryogenic pumping. When this occurs the vacuum valve on the dewar can be closed. The vacuum pump can be turned off, if desired. The hydrogen vapor pressure thermometer on the dewar will drop slowly at first and after 15 to 20 minutes or so will reach about 70 psia at which point it will drop quickly to near zero indicating a temperature below the 26K operating point has been reached. Note the time and readings in the DETECTOR COOLER OPERATING LOG.

Then turn on the detector cooler temperature control in the receiver auxiliary stand using previous operating log readings as a guide. The TEMP. dial settings are not calibrated but D300 to D400 can be used as a start with the SENSITIVITY dial set near zero. If the meter on the detector cooler controller does not go up-scale increase the SENSITIVITY slightly (0.01 or so). The meter normally oscillates for a few minutes during which time the hydrogen pressure rises indicating that the heater is warming the cold head intermittently. If the oscillations do not die out after several minutes decrease the SENSITIVITY slightly; the setting seems to be rather critical. The hydrogen pressure of 58 psia ± 1 psia corresponds to the normal cold head temperature of 26K ± 1K. Change the TEMP dials on the detector cooler temperature controller until the desired temperature is obtained. Preliminary tests indicate any pressure between 50 to 60 psia will be satisfactory. Perhaps even wider limits can be used. After the temperature has stabilized record the time and readings in the DETECTOR COOLER OPERATING LOG. The detector cooler is now ready for operation.

5.3.3 Choppers

The choppers need to be turned on beforehand because of small drifts which occur during warm-up. These drifts are greatest just after turn-on so that after 15 to 30 minutes the choppers can be used if one is willing to tweak the frequency controls of the selective amplifiers and lock-in amplifiers and recheck the phase of the lock-in amplifier. However, for best results the full warm-up time should be allowed. The meter on the source chopper should be set near 170 on the 300 range, which should give a source channel frequency near 570 Hz. The frequency of the reference chopper should be about 330 Hz and normally does not need to be adjusted. With the 110V power applied to the NIM BIN and the logic box and the SYNCH OUTPUT terminals on the control panel connected to the REFERENCE IN/OUT terminals on the lock-in amplifiers the synch signals may be observed on the lock-in amplifiers by setting the METER/MON. switch to REF. The meter reading is normally about 0.80 of full scale with the normal setting of the REFERENCE LEVEL control on the lock-in amplifier. Such a reading indicates that the choppers are working properly and are ready for operation.

5.4 TEST PARAMETER SELECTION

There are a number of parameters which must be selected in order to operate the ROSE system. The basis for selection of these parameters is discussed in this section. A SYSTEM OPERATING LOG is provided in which these parameters should be recorded; data is practically worthless if the parameters are not known. Completion of the log will aid in discovering controls which are not set in the proper position.

It will be convenient to assign run identification (I.D.) numbers by means of which different records may be later identified and analyzed by reference to the SYSTEM OPERATING LOG. Five digits can be recorded on the digital recording system; a run I.D. number consisting of the month day and run sequence number has been used. For example, the second run on March 27 would have a run I.D. number of 32702. The date is still necessary to distinguish between November and January or December and February and to record the year.

The parameter selections are grouped into spectral parameters, slit height and width selection, time constant-scan speed relations and consideration of selective amplifier Q.

5.4.1 Spectral Parameters

Spectral Region of Interest

The first parameter to be selected is the spectral region of interest. This may be one entire band or only a small portion of a band of particular interest. There are two wavelength bands which are designated (for identification) 3-5.5 microns and 7-13.5 microns.

Electrical limit switches restrict the wavenumber regions from about 1410 to 3830 cm^{-1} (7.1μ to 2.6 microns) for the "3-5.5 micron" band (240 L/mm) and from about 590 to 1610 cm^{-1} (16.8 to 6.2 microns) for the "7-13.5 micron" band (101 L/mm). The useful wavenumber limits depend mainly on range because of the absorption by normal atmospheric constituents.

The short wavelength cutoff filters restrict the wavelengths to approximately $\lambda > 2.8$ microns ($\nu < 3600$ cm^{-1}) for the 3-5.5 micron band and to $\lambda > 7.0$ microns ($\nu < 1430$ cm^{-1}) for the 7-13.5 micron band.

Every effort should be made to reduce the region of interest to that actually necessary because of the time required for slow scans with long-time constants

Grating

The 240 L/mm grating is used for the 3-5.5 micron band and the 101 L/mm grating is used for the 7-13.5 micron band. The selection is made by means of a control on top of the monochromator (see Section 5.5.1).

Filter

Normally there is a short wavelength cutoff filter associated with each grating. A 3 micron cutoff filter is used with the 240 L/mm grating for the 3-5.5 micron band and a 7 micron cutoff filter is used with the 101 L/mm grating for the 7-13.5 micron band. However, there are occasions for which other combinations may be used. For example, a higher order H_2O band was used to perform a wavenumber calibration and, in this case, no filter was used.

The filter selection is made by means of a knob (on top of the monochromator) which controls a filter wheel. Positions for each spectral band are labelled along with OPEN and SHUT positions of the filter wheel.

5.4.2 Slit Height

The slit height in the transmission made of operation should be varied according to the range being normally set equal to the image height, h_o, as indicated on Figure 3.3.2.7. Use of a smaller height cuts down signal; use of a larger height adds no more signal but may reduce the noise from image movement in the vertical direction resulting from atmospheric refraction. For very short ranges, e.g. in the laboratory, a maximum slit height of about 8 mm should be used (see Section 3.4.1); for larger slit heights the ray boundary envelope exceeds the blackbody cavity opening size.

The slit height in the emission mode of operation should be set equal to 12 mm if the object being observed is of sufficient size (see Figure 3.3.2.1). This 12 mm height corresponds to the detector length of 2mm as imaged by the 6X detector optical system on the monochromator slits. The slit height may, of course, be reduced to fit the object of interest but with a loss of signal.

5.4.3 Slit Width

The slit width is probably the most important single test parameter because of its large effect on other operating parameters.

The slit width chosen will depend on the type of test being run and the character of the spectra being examined. It is convenient for functional checking to use a standardized set of parameters. A slit width, s, of 700 microns is used for the 3-5.5 micron band and a slit width of 300 microns is used for the 7-13.5 micron band. Variations of the signal obtained in these functional checks may indicate a need for realignment, retuning or other action.

The maximum slit width is about 1200 microns which corresponds to the 200 micron detector image formed by the 6X detector optical system.

Under the conditions of laboratory or field operation that best slit width will, almost always, be determined empirically using several trial widths. The choice will be governed mainly by the signal available, noise and the spectral line width and spacing in the spectra of interest or in spectra of interfering gases. The discussion given below will help to choose the proper slit width and shows its effect on the other operating parameters of signal to noise ratio, scan rate and time constant.

Single Line Signal

The instrument response to an isolated spectral line having an effective or equivalent width, $\Delta\nu_L$, which is about the same as the spectral slit width, $\Delta\nu$, is the convolution of the line shape* and the slit function. The details of the response depend on the details of both the line shape and the slit function. The analysis of such an output and the "deconvolution" of the output to obtain the line shape are too complex to discuss here in the time and space available.

The area of an output transmission curve between the curve respresenting the line response and the curve (or baseline) without the line is not dependent on detailed knowledge of either the line shape or the slit function. It is sufficient for the present purposes to define the area referred to above in terms of the line width and slit function width.

Figure 5.4.3.1 shows schematically the instrument response to a single line. It might seem, at first, that $\Delta\nu$ should be made as small as possible to increase the deflection for a given value of $\Delta\nu_L$. It must be remembered, however, that the curve shown is a relative transmission curve. The output signal is the product of the transmission curve (T/T_o) and the baseline or background signal. For a continuum background this signal equals

$$S_B = K_1 \frac{J}{J_o} s \, \Delta\nu = K_1 \frac{J}{J_o} s^2 (d\nu/ds)$$

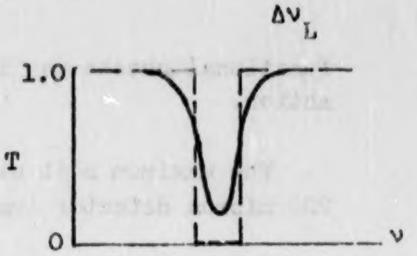
where K_1 involves factors of radiance difference, $A\Omega/s$, transmission, modulation factor, etc., s is the slit width and $\Delta\nu$ is the slit function width.

---

*Line shape as used here refers to the absorptivity or transmissivity vs wavenumber curve.

For an Absorbing Line

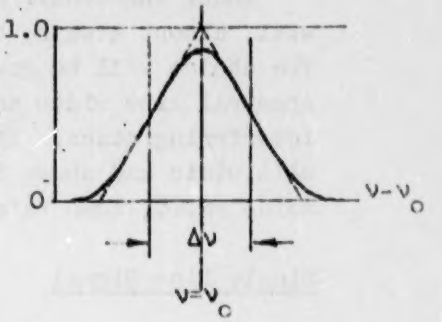
$$\Delta\nu_L[1-(T=0)] = \int_{\text{Line}} (1-T)\, d\nu$$

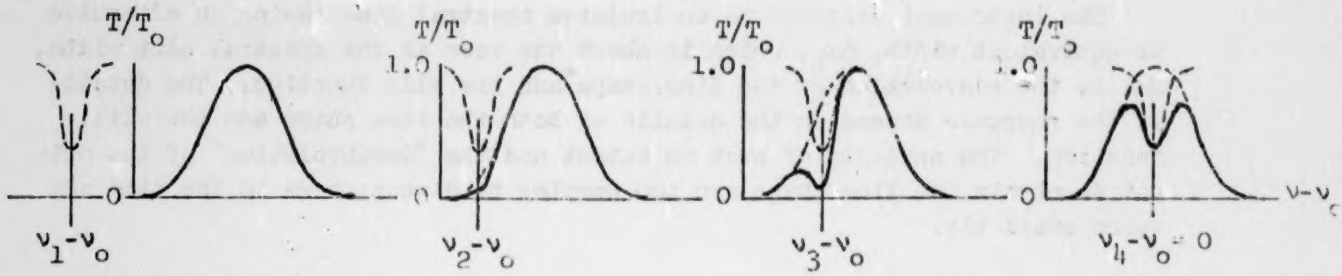


For the Slit Function

$$\Delta\nu = \int \left(\frac{T}{T_o}\right) d(\nu-\nu_o)$$

ν_o = Instrument Wavenumber Setting





$$\overline{\left(\frac{T}{T_o}\right)}\Delta\nu = \int \left(\frac{T}{T_o}\right) d(\nu-\nu_o) = \left(\frac{T}{T_o} = 1.0\right)(\Delta\nu-\Delta\nu_L)(f(\nu-\nu_o))$$

$$\overline{\left(\frac{T}{T_o}\right)}_{MIN} \approx \frac{\Delta\nu-\Delta\nu_L}{\Delta\nu}$$

$$1 - \overline{\left(\frac{T}{T_o}\right)}_{MIN} \approx \frac{\Delta\nu_L}{\Delta\nu}$$

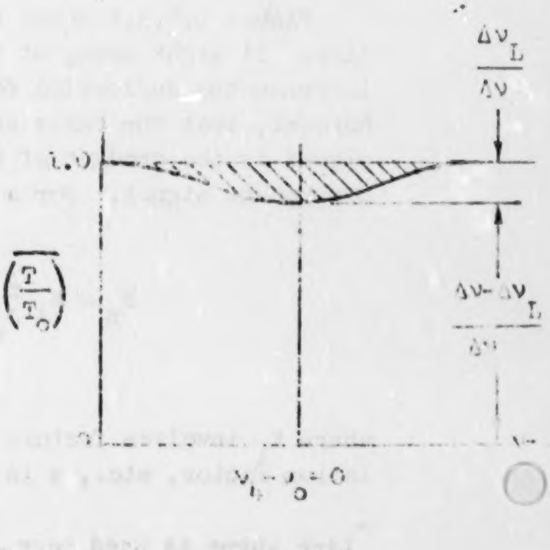


Figure 5.4.3.1 Spectral Line Response

The factor (J/J_o) is an irradiance ratio discussed later. Since $\Delta\nu$ is proportional to s, the background, S_B, is proportional to s^2.

The maximum height of the "line" output signal, S_L, is

$$S_L = \left(1 - \frac{\bar{T}}{T_o}\right) S_B$$

$$\cong \frac{\Delta\nu_L}{\Delta\nu} K_1 \frac{J}{J_o} s\Delta\nu$$

$$= K_1 \frac{J}{J_o} s\,\Delta\nu_L$$

Thus, S_L, depends on the first power of the slit width, s.

The factor $(d\nu/ds)$ in the equation for S_B deserves some comment for the case in which the slit width is comparable to the diffraction pattern half width, $a = \lambda F/D$. When the slits are wide, $(s/a) >> 1.0$, the value of $d\lambda/ds$ (or $d\nu/ds$) is essentially equal to that calculated from the grating equation, $(d\nu/dx)_g$ (or $(d\lambda/dx)_g$; see Section 3.3.5. When (s/a) is comparable to 1.0 the image at the exit slit is spread out and the slope $d\nu/ds$ decreases as shown on Figure 5.4.3.2. These curves were calculated from the analysis referred to in Section 3.3.5 for incoherent illumination of the entrance slit. Although the coherence increases as the slit is closed such effects are not considered here because the effects of the coherence change are relatively unimportant to the main subject of slit width selection.

The equations for S_B and S_L also contain a term, (J/J_o), which is of importance when s is comparable to a. This term is the relative irradiance at the center of the exit slit resulting from the spreading of the image by diffraction. Figure 5.4.3.3 shows the relative irradiance as a function of (s/a) calculated from the analysis of Section 3.3.5.

This factor is of importance only for values of (s/a) below about 2 or 3; e.g., slit widths less than about 100 to 150 microns at $\lambda = 10$ microns for the present f/5 system.

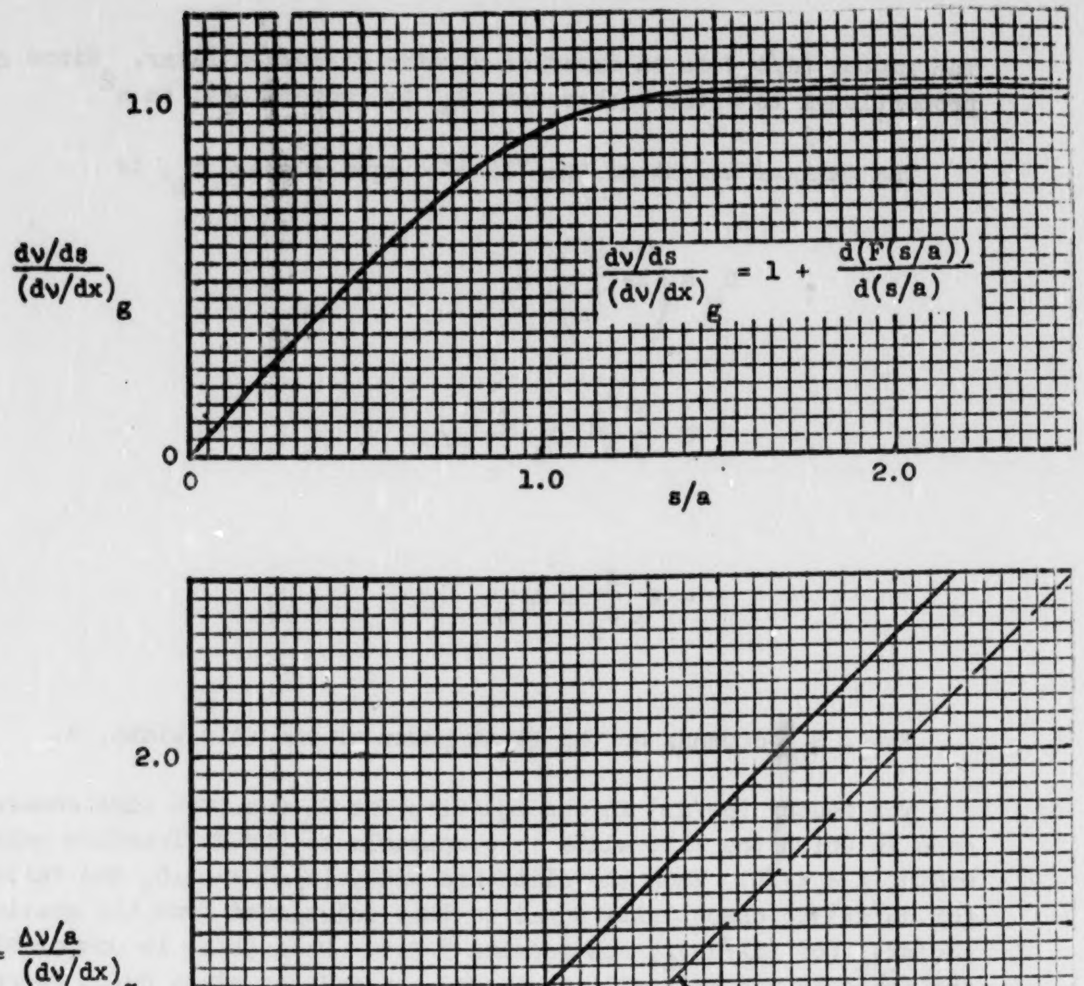


Figure 5.4.3.2 dv/dx vs. s/a

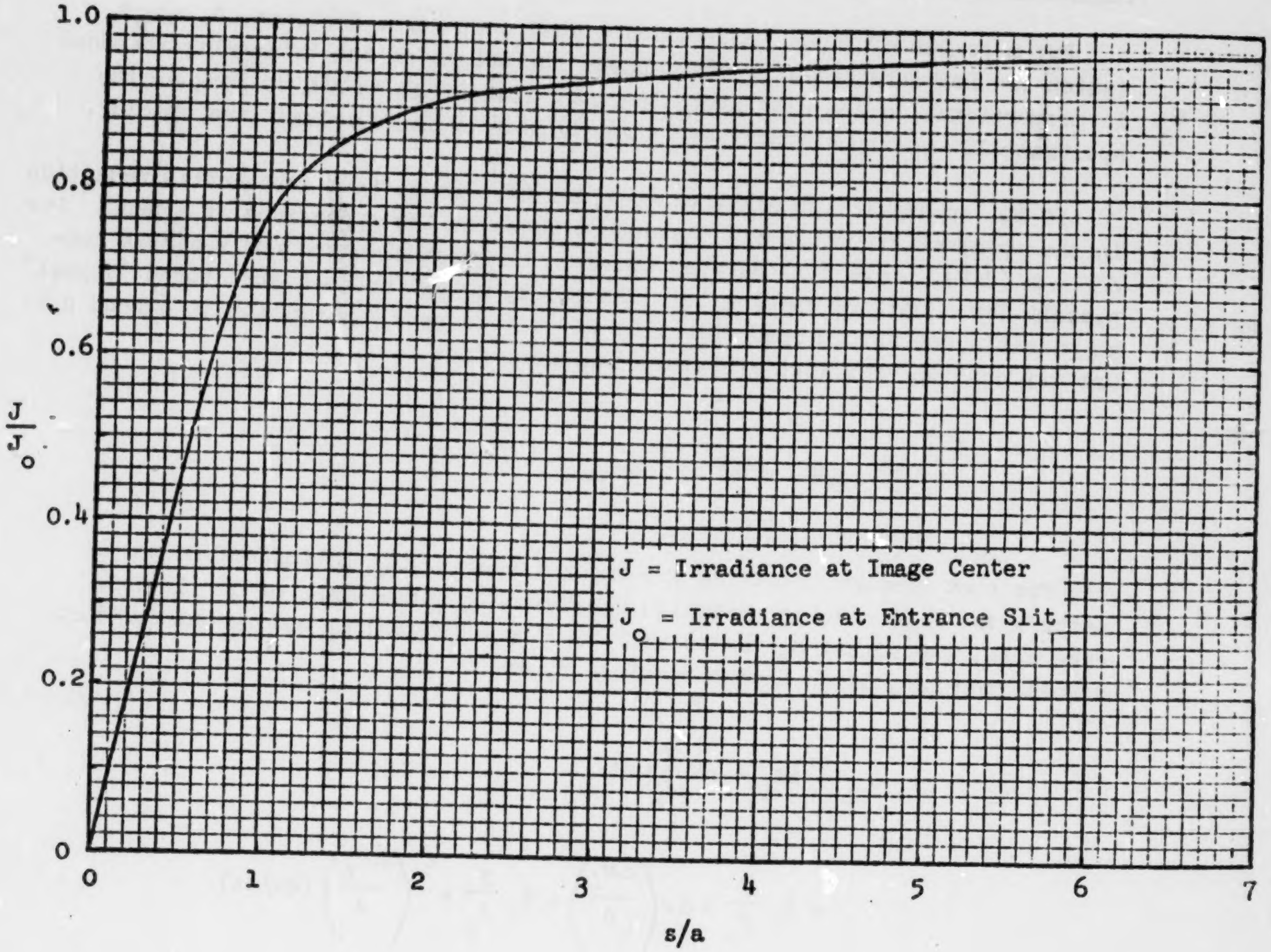


Figure 5.4.3.3 Exit Slit Irradiance

The instrument response to an isolated spectral line having an effective width, $\Delta\nu_L$, narrow compared to the slit function width, $\Delta\nu$, is a triangular deviation from the baseline. The equations for S_B and S_L given before apply here also.

Groups of Lines Signal

For a series of lines ($\Delta\lambda_L << \Delta\lambda$) spaced a spectral distance, d, apart (which are not substantially overlapped) the height of the triangular response is proportional to the slit width (through its effect on $A\Omega$) so long as the spectral slit width is less than (d/2) where d is the spectral line spacing.

If the spectral slit width exceeds d/2 then there is a substantial reduction in the spectral structure and the output takes on the appearance of a band. For $\Delta\nu = m\,(d/2)$, where m is an even number, the spectral structure vanishes completely for a uniform spacing, d. Therefore, to get as much structured "signal" as possible one should open the slits as wide as possible but not to exceed d/2. One may consider for line structure the criterion:

$$\Delta\lambda_{max} < (d/2)\mu \quad \text{or} \quad \Delta\nu_{max} < (d/2)\ \text{cm}^{-1}$$

For some spectra involving groups of lines it will be impossible to satisfy the line spacing criterion because of the smallness of d. In this case also, the signal S_B varies with $s\Delta\nu$ or $s^2(d\nu/ds)$ as before but the band signal from many lines having spacing, d, is

$$S_{NL} = nS_L = nK_1 \frac{J}{J_o} s\Delta\nu_L$$

$$= K_1 \frac{J}{J_o} s\Delta\nu \left(\frac{\Delta\nu_L}{d}\right) = K_1 \frac{J}{J_o} s^2 \left(\frac{\Delta\nu_L}{d}\right) (d\nu/ds)$$

where n = number of lines within the slit width $\Delta\nu$

= $\Delta\nu/d$ has been included in the factor K.

Thus, the band signal for a given set of lines will increase with $s\Delta\nu = s^2\,(d\nu/ds)$ also.

Signal to Noise

To determine the slit widths appropriate to various signal and noise conditions consider the case in which the noise is not a function of the signal, i.e., either detector noise limited or system noise limited.

$$\frac{S}{N} = \frac{\text{Signal}}{\text{Noise}} = \frac{(\Delta N(\nu))(A\Omega/s)\Delta\nu(1-\alpha)\tau M}{(\text{Constants})\ D^*\sqrt{A_d\Delta_f}}\, s$$

For a line,

$$\frac{S_L}{N} = K_2\frac{J}{J_o}\, s\,\Delta\nu_L\sqrt{\tau} \qquad (\Delta\nu < d/2)$$

For a continuum baseline,

$$\frac{S_B}{N} = K_2\frac{J}{J_o}\, s\,\Delta\nu\sqrt{\tau} = K_2\frac{J}{J_o}\, s^2\ (d\nu/ds)\sqrt{\tau}$$

For a group of lines,

$$\frac{S_{NL}}{N} = K_2\frac{J}{J_o}\, s\,\Delta\nu\left(\frac{\Delta\nu_L}{d}\right)\sqrt{\tau} = K_2\frac{J}{J_o}\, s^2\left(\frac{\Delta\nu_L}{d}\right)(d\nu/ds)\sqrt{\tau}$$

where K_2 includes K_1 and all of the factors in the noise except bandwidth, Δf, or what is equivalent, τ, the system time constant. If the noise is independent of the signal, these relations indicate that the longest available time constant τ, and the largest slit width, s, should be used (subject to ($\Delta\nu < d/2$) for the display of lines). A scan speed consistent with this time constant would then be selected according to Section 5.4.4.

The above equations do not reveal, however, the powerful effect of the slit width on the other operating parameters; the scan rate ($d\nu/dt$) and time constant, τ.

The following relations are used in the analysis:

$$\Delta\nu = (d\nu/ds)\, s$$

$$\Delta t = \frac{\Delta\nu}{(d\nu/dt)} = \frac{(d\nu/ds)\, s}{(d\nu/dt)}$$

$$\tau \propto \Delta t \qquad \text{(see Section 5.4.4)}$$

$$N \propto \sqrt{\Delta f} \propto \sqrt{\frac{1}{\tau}}$$

$$= \text{noise}$$

Consider two operating conditions which are denoted by subscripts 1 and 2. First, for isolated spectral lines, the ratio, R_L, of the signal to noise ratios may be written as follows.

$$\frac{(S_L/N)_2}{(S_L/N)_1} = \frac{(J/J_o)_2}{(J/J_o)_1} \; \frac{s2}{s1} \sqrt{\frac{\tau_2}{\tau_1}} = R_L$$

$$= \frac{(J/J_o)_2}{(J/J_o)_1} \; \frac{s2}{s1} \left[\frac{(d\nu/dt)_1}{(d\nu/dt)_2} \; \frac{(d\nu/ds)_2}{(d\nu/ds)_1} \; \frac{s2}{s1} \right]^{\frac{1}{2}}$$

The scan rate ratio may be expressed:

$$\frac{(d\nu/dt)_1}{(d\nu/dt)_2} = R_L^{\;2} \left[\frac{(J/J_o)_1}{(J/J_o)_2} \right]^2 \left(\frac{s1}{s2} \right)^3 \; \frac{(d\nu/ds)_1}{(d\nu/ds)_2}$$

For large slit widths (compared to a)

$$\frac{(J/J_o)_1}{(J/J_o)_2} \text{ and } \frac{(d\nu/ds)_1}{(d\nu/ds)_2} = 1.0$$

$$\frac{(d\nu/dt)_1}{(d\nu/dt)_2} = R_L^{\;2} \left(\frac{s1}{s2} \right)^3 \qquad ((s/a) \gg 1.0)$$

For the same signal to noise ratio at the two test conditions, $R_L = 1.0$,

$$\frac{(d\nu/dt)_1}{(d\nu/dt)_2} = \left(\frac{s1}{s2}\right)^3 \qquad (s/a) \gg 1.0;\ R_L = 1.0)$$

Thus, if the noise on the trace is to be the same fraction of the height of the "line" response, a reduction of the slit by a factor of 2 would require a reduction of scan speed by a factor of 8 if $(s/a) \gg 1.0$.

The time constant ratio may be written:

$$\frac{\tau_2}{\tau_1} = R_L^{\ 2} \left[\frac{(J/J_o)_1}{(J/J_o)_2}\right]^2 \left(\frac{s1}{s2}\right)^2$$

and for wide slits

$$\frac{\tau_2}{\tau_1} = R_L^{\ 2} \left(\frac{s1}{s2}\right)^2 \qquad ((s/a) \gg 1.0)$$

For the same signal to noise ratio

$$\frac{\tau_2}{\tau_1} = \left(\frac{s1}{s2}\right)^2 \qquad ((s/a) \gg 1.0;\ R_L = 1)$$

In the previous case of a slit width reduction by a factor of 2, the time constant would have to be increased by a factor of 4.

The effect of the terms $(J/J\ )$ and $(d\nu/ds)$ on the scan speed and time constant ratios are shown below (using Figures 5.4.3.2 and 5.4.3.3).

$s1/a$	$s2/a$	$\frac{(d\nu/ds)_1}{(d\nu/ds)_2}$	$\frac{\tau_2}{\tau_1}$
12	6	8	4
2	1	6.4	5.6
1	0.5	21.5	11.6

For the baseline signal, S_B, or for the signal from a group of lines (or a band), S_{NL}, the signal to noise ratio may be written as follows for the two cases as before.

$$\frac{(S_B/N)_2}{(S_B/N)_1} = \frac{(S_{NL}/N)_2}{(S_{NL}/N)_1} = \frac{(J/J_o)_2}{(J/J_o)_1} \left(\frac{s2}{s1}\right)^2 \frac{(d\nu/ds)_2}{(d\nu/ds)_1} \sqrt{\frac{\tau_2}{\tau_1}} = R_B$$

$$= \frac{(J/J_o)_2}{(J/J_o)_1} \left(\frac{s2}{s1}\right)^2 \frac{(d\nu/ds)_2}{(d\nu/ds)_1} \left[\frac{(d\nu/dt)_1}{(d\nu/dt)_2} \frac{(d\nu/ds)_2}{(d\nu/ds)_1} \frac{s2}{s1}\right]^{\frac{1}{2}}$$

The scan rate ratio may be expressed:

$$\frac{(d\nu/dt)_1}{(d\nu/dt)_2} = R_B^{\ 2} \left[\frac{(J/J_o)_1}{(J/J_o)_2}\right]^2 \left(\frac{s1}{s2}\right)^5 \left[\frac{(d\nu/ds)_1}{(d\nu/ds)_2}\right]^3$$

For large slit widths (compared to a)

$$\frac{(d\nu/dt)_1}{(d\nu/dt)_2} = R_B^{\ 2} \left(\frac{s1}{s2}\right)^5 \qquad ((s/a) >> 1.0)$$

and for $R_B = 1.0$

$$\frac{(d\nu/dt)_1}{(d\nu/dt)_2} = \left(\frac{s1}{s2}\right)^5 \qquad ((s/a) >> 1.0;\ R_B = 1.0)$$

The time constant ratio may be written:

$$\frac{\tau_2}{\tau_1} = R_B^{\ 2} \left[\frac{(J/J_o)_1}{(J/J_o)_2}\right]^2 \left(\frac{s1}{s2}\right)^4 \left[\frac{(d\nu/ds)_1}{(d\nu/ds)_2}\right]^2$$

For large slit widths (compared to a)

$$\frac{\tau_2}{\tau_1} = R_B^{\ 2} \left(\frac{s1}{s2}\right)^4 \qquad ((s/a) \gg 1.0)$$

and for $R_B = 1.0$

$$\frac{\tau_2}{\tau_1} = \left(\frac{s1}{s2}\right)^4 \qquad ((s/a) \gg 1.0;\ R_B = 1.0)$$

An example of the ratios of scan rate and time constant is given in the table below for a ratio of $(s1/s2) = 2$ as before ($R_B = 1.0$).

$s1/a$	$s2/a$	$\frac{(d\nu/dt)_1}{(d\nu/dt)_2}$	$\frac{\tau_2}{\tau_1}$
12	6	32	16
2	1	67	29
1	0.5	580	135

Thus, large reductions in scanning speed and increases in time constant are required to maintain signal to noise ratios for slit widths comparable to the diffraction pattern width.

The relations developed above will be useful for determining the effect of changes in slit width on the signal to noise ratios and the resulting changes in scan speed and time constant.

The products of the terms (J/J_o) and $(d\nu/ds)$ which depend on (s/a) are shown, raised to the appropriate powers, on Figure 5.4.3.4. For slit widths greater than about 2a the effects of diffraction on scan rate ratio or time constant ratio are not important.

5.4.4 Time Constant-Scan Speed Relations

The selection of the lock-in amplifier time constant and the monochromator scan speed will depend on the spectral and temporal nature of the object of interest. In those cases in which the source of interest varies appreciably with time, this fact will dominate the choice of scanning speed. Particularly

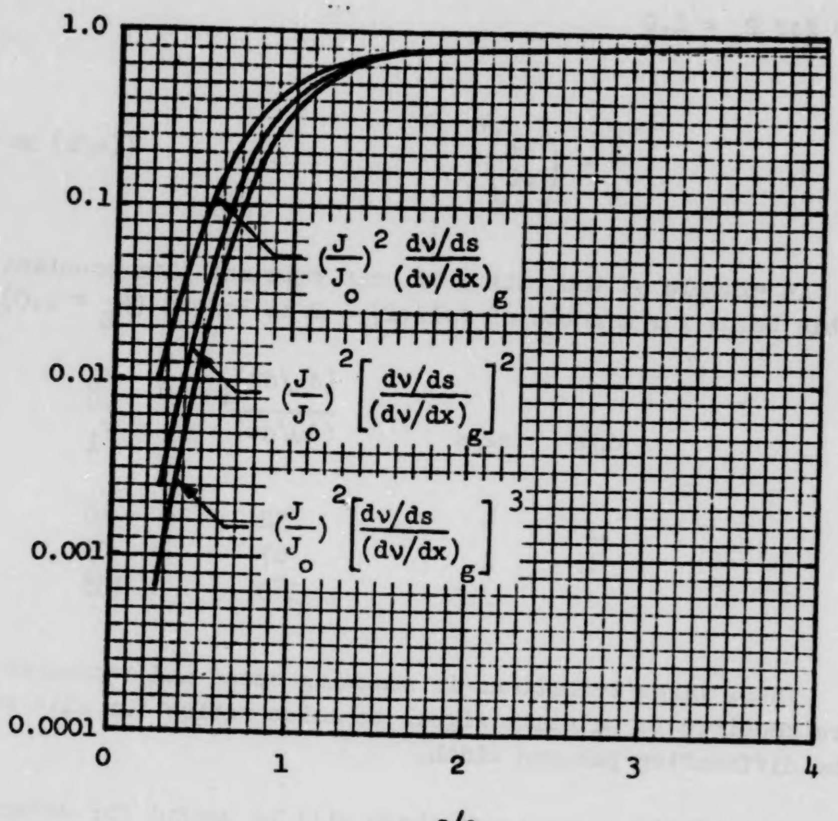


Figure 5.4.3.4 Diffraction Parameters

in these cases it will be helpful to scan no wider a region than necessary. The lock-in amplifier time constant would be chosen to be compatible with the selected scan speed based either on the criterion of the permissible wavenumber shift or of the permissible error at the peak of the slit function representing a spectral line as described in this section.

For cases in which the source of interest is not varying appreciably with time, a choice of scanning speed is possible.

The lock-in amplifier time constant selection from 0.01 sec. to 1.0 second allows control of system bandwidth and noise. Generally, the shortest time constant consistent with a satisfactory noise level should be used. Longer time constants will reduce noise but also degrade the system ability to respond to a rapidly changing signal, i.e., a spectral line.

Consider a triangular pulse (representing the spectral response to a narrow line) as the input to a low pass RC filter. The filter output has two major distortions; there is a delay and there is an error at the peak (see Figure 5.4.4.1).

If the time constant, $\tau = RC$, is short compared to the pulse width at half height, $\Delta t = \Delta\lambda/(d\lambda/dt) = \Delta\nu/(d\nu/dt)$, then the delay will approach τ for both the rising and falling portions of the output pulse. The peak will be delayed about 0.69τ and the peak error (for a unit input peak) will be about $0.69\tau/\Delta t$.

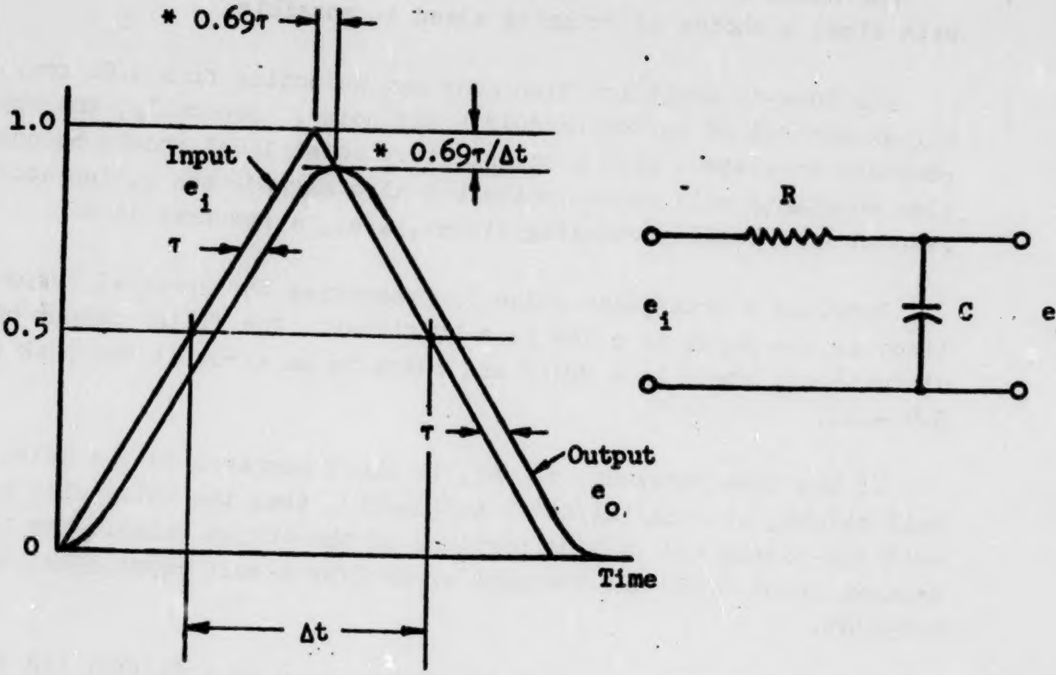
For the rising portion of the input, $e_i = \alpha t = (1/\Delta t)t$ and the output is

$$e_o = \alpha(t - RC) + \alpha RC\, e^{-t/RC}$$

For the falling portion of the input, $e_i = 1 - \alpha t'$ with a shift of the time axis to the input peak. Assumingthe rising portion of the output is negligibly different from its asymptotic rate of change, the output is

$$e_o = 1 - \alpha(t'-RC) - 2\alpha RC_e^{-t'/RC} .$$

Differentiating e_o and setting it to zero leads to a time delay of the peak, $t'_p = 0.693RC = 0.693\tau$. The error in the output peak is



Assume negligible source impedance and load.

* $\tau \ll \Delta t$

Figure 5.4.4.1 RC Filter Response

$$E_p = (e_{ip} - e_{op})/e_{ip} = 1 - e_{op} = 0.693\alpha RC = 0.693\tau/\Delta t$$

If the delay is set equal to the time corresponding to the smallest resolution element $\tau_d = 0.1\ \text{cm}^{-1}/(d\nu/dt)$ and from the wavenumber calibration, $d\nu/dt = (\text{RPM}/60)B$, where RPM = Monochromator scan speed and B is the number of cm^{-1} per drum turn,

$$\tau_d = \frac{0.1(60)}{(\text{RPM})B}\ \text{sec.}$$

For the 240L/mm grating, $B = 123.9\ \text{cm}^{-1}$/turn and, at the fastest speed of 6 R[illegible] $\tau_d = 0.008$ sec. For the 101L/mm grating, $B = 52.2\ \text{cm}^{-1}$/turn and, again at 6 RPM, $\tau_d = 0.02$ sec. Thus, within a factor of two, a time constant of about 0.01 sec is appropriate for the fastest scan speed. Figure 5.4.4.2 shows the time constant corresponding to $0.1\ \text{cm}^{-1}$ delay for the available scan speeds.

For other time constant settings the delay in cm^{-1} is proportional to the τ setting. Values may be obtained by the ratio

$$\text{Delay}\ (\text{cm}^{-1}) = \frac{\tau}{\tau_d}\ (0.1\ \text{cm}^{-1})$$

where τ_d may be read from the figure.

Note that, for either grating and a $0.1\ \text{cm}^{-1}$ delay,

$$\tau_d(\text{RPM})(\text{L/mm}) \sim 0.1(60)(\text{L/mm})/B$$

$$6\ (1.94) \sim 11.6 \sim 12.$$

This is a useful relation if operating charts are not at hand.

Let the value of Δt be evaluated for the best specified resolution of 0.01 micron. The corresponding values of $\Delta\nu$ vary from $11.1\ \text{cm}^{-1}$ at $3333\ \text{cm}^{-1}$ (3μ) to $3.3\ \text{cm}^{-1}$ at $1820\ \text{cm}^{-1}$ (5.5μ) for the 240 L/mm grating and $2.0\ \text{cm}^{-1}$ at $1430\ \text{cm}^{-1}$ (7μ) to $0.55\ \text{cm}^{-1}$ at $740\ \text{cm}^{-1}$ (13.5μ) for the 101 L/mm grating.

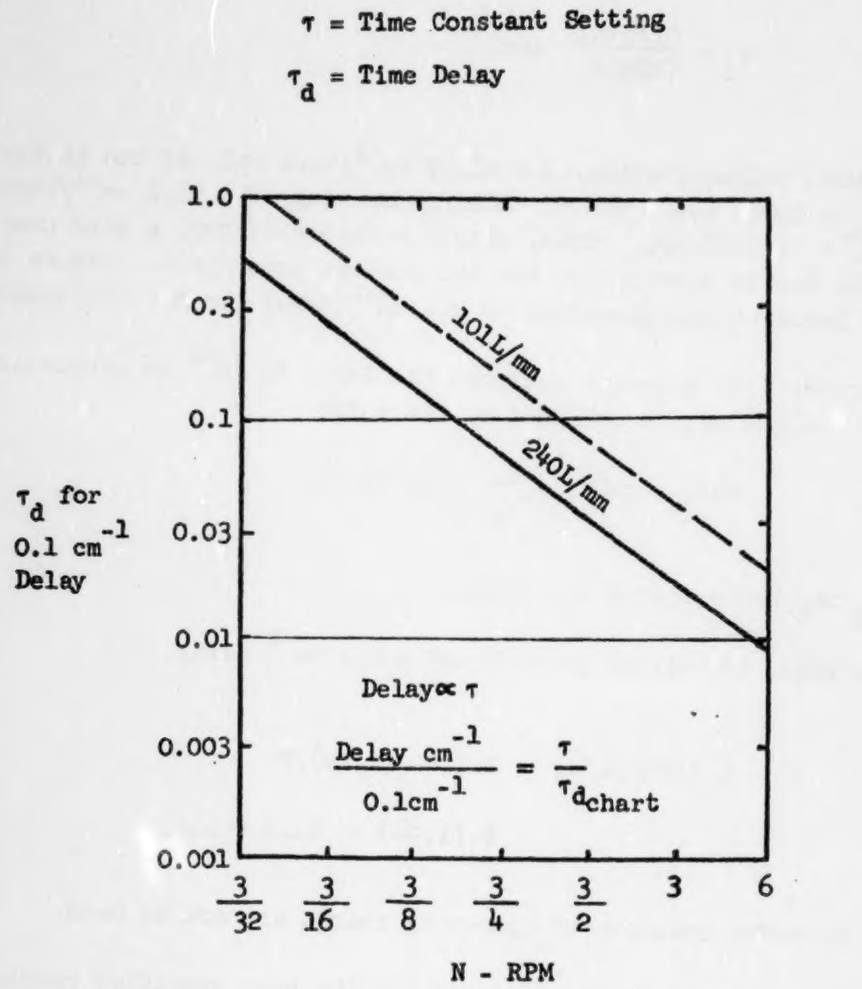


Figure 5.4.4.2 Time Constant - 0.1 cm^{-1} Delay

$$\Delta t = \frac{\Delta\nu 60}{(\text{RPM})B}$$

	λ	$\Delta\nu$	6 RPM		
			Δt	τ	$0.69\tau/\Delta t$
240 L/mm	3μ	11.1 cm^{-1}	0.90	0.008	0.006
	5.5μ	3.3	0.27	0.008	0.020
101 L/mm	7μ	2.0	0.38	0.02	0.036
	13.5μ	0.55	0.10	0.02	0.138

Thus, the peak error grows with wavelength and, for this fastest scan speed, reaches about 14% at 13.5 microns even with the short time constant. This can be reduced by decreasing the scan speed. Figure 5.4.4.3 shows the peak error for the spectral band of each grating for the range of available scan speeds and a time constant setting of 0.01 second and a spectral bandwidth of 0.01 micron.

From the figure it may be seen that in order to have 1% or less peak error over the 3 to 5.5 micron band a maximum speed of about 3 RPM can be used. Similarly, for the 7 to 13.5 micron band a speed of no more than about 3/4 RPM can be used for a 1% peak error. The peak error for other time constants and spectral bandwidths is proportional to $(\tau/\Delta\lambda)$. Thus for $\tau = 1.0$ sec. and the 101 L/mm grating ($\Delta\lambda = 0.01\mu$) a scan speed of 3/32 RPM will give about .001 $(1.0/0.01) \sim 0.1$ or 10% peak error at 13.5 microns and about 3% peak error at 7 microns. With the 240 L/mm grating ($\Delta\lambda = 0.01\mu$), $N = 3/32$ RPM and $\tau = 1.0$ sec. the peak error is about 4% at 5.5 microns and about 1% at 3 microns. From Figure 5.4.4.2 the delay with $\tau = 1.0$ sec and $N_1 = 3/32$ RPM would be about 0.08 cm^{-1} with the 101L/mm grating and about 0.2 cm^{-1} with the 240 L/mm grating.

It is evident that for the maximum resolution the scan speeds must be slow in order to avoid distortion particularly of the output peak amplitude. However, note that even with error at the peak, a better approximation to the peak can be obtained by extrapolating the two sides of the slit function to an intersection if $\tau < \Delta t$.

A logical approach to the selection of the proper time constant and scan speed is shown on Figure 5.4.4.4. The diffraction parameters are omitted for brevity but should be included in the calculation if the slit width is comparable to a.

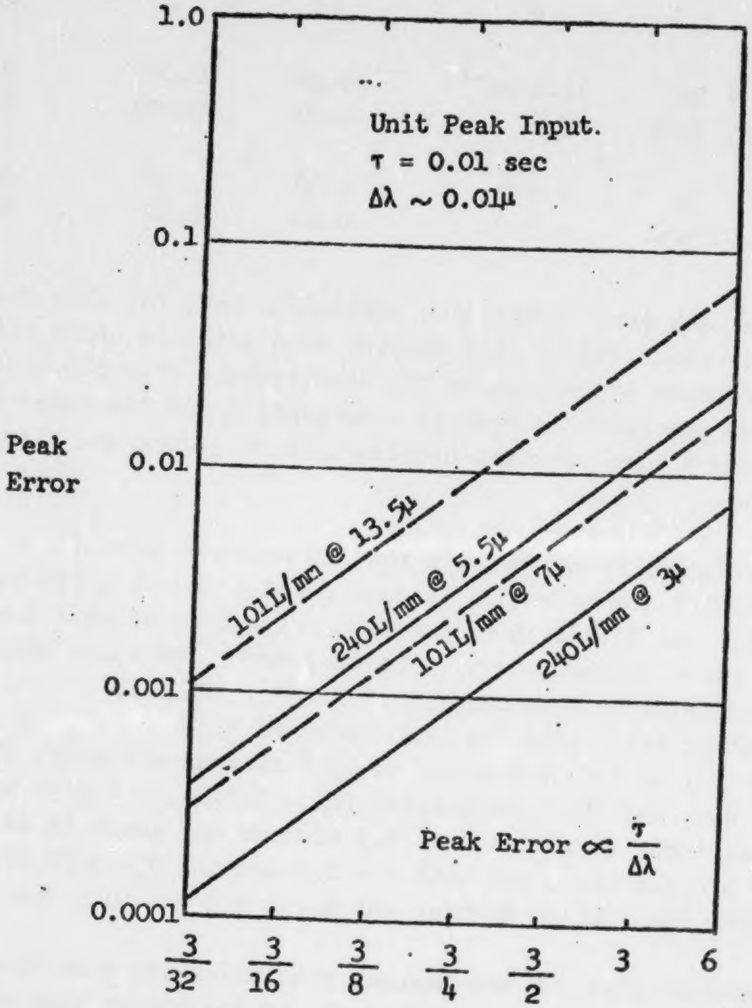


Figure 5.4.4.3 Time Constant - Peak Error

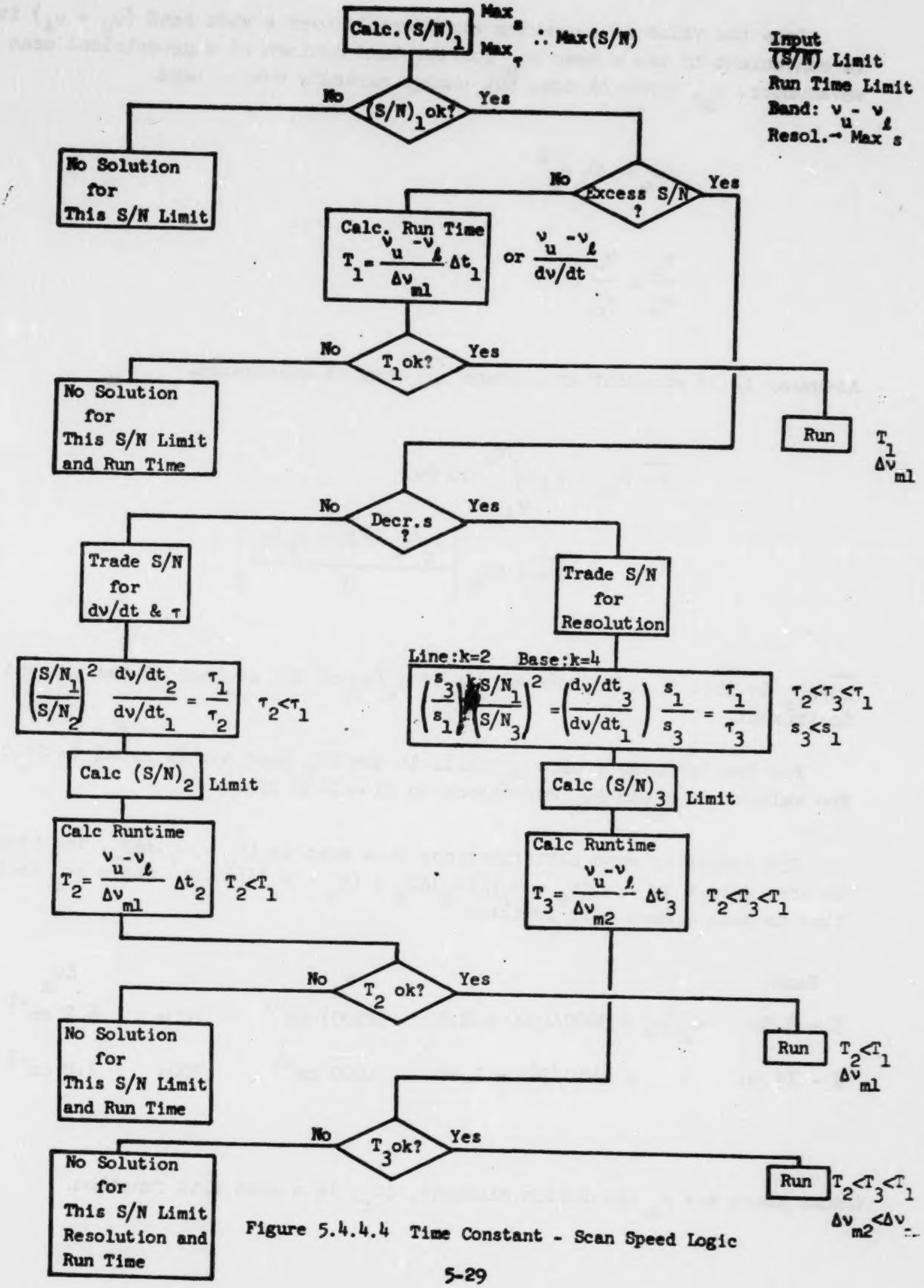

Calc. $(S/N)_1$
Max_s
Max_τ
∴ Max(S/N)
Input
(S/N) Limit
Run Time Limit
Band: $\nu_u - \nu_\ell$
Resol. → Max_s
No
$(S/N)_1$ ok?
Yes
No Solution for This S/N Limit
No
Excess S/N ?
Yes
Calc. Run Time
$T_1 = \frac{\nu_u - \nu_\ell}{\Delta\nu_{m1}} \Delta t_1$ or $\frac{\nu_u - \nu_\ell}{d\nu/dt}$
No
T_1 ok?
Yes
No Solution for This S/N Limit and Run Time
Run
T_1
$\Delta\nu_{m1}$
No
Decr. s ?
Yes
Trade S/N for dν/dt & τ
Trade S/N for Resolution
Line: k=2
Base: k=4
$\left(\frac{S/N_1}{S/N_2}\right)^2 \frac{d\nu/dt_2}{d\nu/dt_1} = \frac{\tau_1}{\tau_2}$
$\tau_2 < \tau_1$
$\left(\frac{s_3}{s_1}\right)^k \left(\frac{S/N_1}{S/N_3}\right)^2 = \left(\frac{d\nu/dt_3}{d\nu/dt_1}\right) \frac{s_1}{s_3} = \frac{\tau_1}{\tau_3}$
$\tau_2 < \tau_3 < \tau_1$
$s_3 < s_1$
Calc $(S/N)_2$ Limit
Calc $(S/N)_3$ Limit
Calc Runtime
$T_2 = \frac{\nu_u - \nu_\ell}{\Delta\nu_{m1}} \Delta t_2$
$T_2 < T_1$
Calc Runtime
$T_3 = \frac{\nu_u - \nu_\ell}{\Delta\nu_{m2}} \Delta t_3$
$T_2 < T_3 < T_1$
No
T_2 ok?
Yes
No Solution for This S/N Limit and Run Time
Run
$T_2 < T_1$
$\Delta\nu_{m1}$
No
T_3 ok?
Yes
No Solution for This S/N Limit Resolution and Run Time
Run
$T_2 < T_3 < T_1$
$\Delta\nu_{m2} < \Delta\nu_{m1}$

Figure 5.4.4.4 Time Constant - Scan Speed Logic

Since the value of $\Delta\nu$ varies considerably over a wide band $(\nu_u - \nu_\ell)$ it is convenient to use a mean $\Delta\nu_m$ for the band defined at a geometrical mean wavenumber, ν_m, since $\Delta\lambda$ does not change markedly over a band.

$$\Delta\nu_m = \Delta\lambda\ \nu_m^2$$

$$\frac{\nu_m}{\nu_\ell} = \frac{\nu_u}{\nu_m}$$

Assuming $\Delta\lambda$ is constant, an average $\overline{\Delta\nu}$ may be calculated.

$$\overline{\Delta\nu}\ (\nu_u - \nu_\ell) = \int_{\nu_\ell}^{\nu_u} \Delta\nu\ d\nu$$

$$\overline{\Delta\nu} = \Delta\nu_m \left[\frac{\nu_u/\nu_\ell + 1 + \nu_\ell/\nu_u}{3}\right]$$

$\overline{\Delta\nu}/\Delta\nu_m$ is less than 1.3 for values of ν_u/ν_ℓ of 2.4 or less of the present instrument.

For the laboratory case ν_m falls in the CO_2 band and is moved to 2500 cm^{-1}. The values of s and $\Delta\nu_m$ correspond to $\Delta\lambda \sim 0.01$ micron.

The number of mean slit functions in a scan is $(\nu_u - \nu_\ell)/\Delta\nu_m$. The time to scan a band is $T = ((\nu_u - \nu_\ell)/\Delta\nu_m)\Delta t_m = (\nu_u - \nu_\ell)/(d\nu/dt)$ where Δt_m is the time to scan a mean slit function.

Band		ν_m	s	$\Delta\nu_m$
3 - 5.5µ	$\nu_u/\nu_\ell = 3600/1500 = 2.4$	(2500) cm^{-1}	700µ	6.2 cm^{-1}
7 - 13.5µ	$= 1410/760 = 1.86$	1000 cm^{-1}	300µ	1.0 cm^{-1}

Assume there are n_m resolution elements, Δt_r, in a mean slit function.

$$n_m = \frac{\Delta\nu_m}{\Delta\nu_r} = \frac{\Delta t_m}{\Delta t_r}$$

where Δt_m = time to scan a mean slit function, $\Delta\nu_m$ and
Δt_r = time to scan a resolution element, $\Delta\nu_r$.

Note that $\Delta\nu$ and Δt are related, in general, by the constant scan rate.

$$\Delta\nu = \Delta t\ (d\nu/dt)$$

At the upper and lower limits of the band

$$\frac{\Delta\nu_u}{\Delta\nu_m} = \left(\frac{\nu_u}{\nu_m}\right)^2 \quad \text{and} \quad \frac{\Delta\nu_\ell}{\Delta\nu_m} = \left(\frac{\nu_\ell}{\nu_m}\right)^2 .$$

The number of resolution elements in the spectral slit width at the upper and lower limits of the band are

$$n_u = \frac{\Delta\nu_u}{\Delta\nu_r} = \frac{\Delta\nu_m(\nu_u/\nu_m)^2}{\Delta\nu_r} = n_m(\nu_u/\nu_m)^2 = n_m(\nu_u/\nu_\ell) \text{ and}$$

$$n_\ell = \frac{\Delta\nu_\ell}{\Delta\nu_r} = \frac{\Delta\nu_m(\nu_\ell/\nu_m)^2}{\Delta\nu_r} = n_m(\nu_\ell/\nu_m)^2 = n_m(\nu_\ell/\nu_u)$$

since $\nu_u/\nu_m = \nu_m/\nu_\ell = (\nu_u/\nu_\ell)^{\frac{1}{2}}$. If $n_m = 10$ and $\nu_u/\nu_\ell = 3$, $n_\ell = 3.3$ and $n_u = 30$.

Let the time delay Δt_d equal the time constant, τ.

$$\Delta t_d = \tau = K\ \Delta t_r$$

$$= K\ \Delta t_m/n_m = K\ \frac{\Delta\nu_r}{d\nu/dt}$$

From the peak error relation,

$$E_p \sim 0.7\ \tau/\Delta t_m = 0.7\ \tau/n_m\Delta t_r = 0.7\ \tau/n_m(\tau/K)$$

$$= 0.7\ K/n_m$$

If $\Delta t_m/\tau \geq 3, (K/n_m)_{max} \sim 0.3$ and $E_{p\ max} \sim 0.23$.

If, for example, $K = 1$ and $n_m = 10$, $K/n_m = 0.1$ $Ep = 0.07$

$K = 1/3$ and $n_m = 10$, $K/n_m = 0.03$ $Ep = 0.02$

Finally,

$$\Delta t_m = n_m \Delta t_r$$

$$= \frac{n_m}{K} \tau$$

$$\tau = \frac{K}{n_m} \Delta t_m = \frac{K}{n_m} \frac{\Delta\nu_m}{d\nu/dt}$$

The time per resolution element is given on Figure 5.4.4.5 as calculated from $\Delta\nu/(d\nu/dt) = \Delta\nu/((RPM/60)B)$.

Time Per Resolution Element (Sec)

		Scan Speed (RPM)						
Grating	Resol.	3/32	3/16	3/8	3/4	3/2	3	6
240L/mm	0.1 cm^{-1}	0.52	0.26	0.13	0.064	0.032	0.016	0.008
	0.2	1.0	0.52	0.26	0.13	0.064	0.032	0.016
	0.5	2.6	1.3	0.64	0.32	0.16	0.08	0.04
	1.0 *	5.2	2.6	1.3	0.64	0.32	0.16	0.08
	2.0	10.4	5.2	2.6	1.3	0.64	0.32	0.16
101L/mm	0.1	1.3	0.64	0.32	0.16	0.08	0.04	0.02
	0.2	2.6	1.3	0.64	0.32	0.16	0.08	0.04
	0.5	6.4	3.2	1.6	0.8	0.4	0.2	0.1
	1.0 *	13.	6.4	3.2	1.6	0.8	0.4	0.2
	2.0	26.	13.	6.4	3.2	1.6	0.8	0.4

* Values in this line also equal $dt/d\nu$ - Sec/cm^{-1}.

Figure 5.4.4.5 Time per Resolution Element

In order to illustrate use of the above relations, consider the two spectral bands of interest run at the maximum specified resolution, $\Delta\lambda = 0.01\mu$, and with the maximum time constant, $\tau = 1.0$ sec. Assume the criterion $\Delta t_m/\tau = 10$ for $E_p \sim 0.07$.

Band (approx.)	3 - 5.5 Micron	7 - 13.5 Micron
$\nu_u - \nu_\ell$ (assumed)	3600-1500 cm^{-1}	1410-760 cm^{-1}
Grating	240 L/mm	101 L/mm
$\Delta\nu_m$	6.2 cm^{-1}	1.0 cm^{-1}
$\Delta t_m/\tau$	10	10
$\Delta\nu_m \tau/\Delta t_m$	0.6 cm^{-1}	0.1 cm^{-1}
$\Delta\nu_m/\Delta t_m$ ($\sim d\nu/dt$ @ $\tau = 1.0$)	0.6 cm^{-1}/sec.	0.1 cm^{-1}/sec.
$\Delta t_m/\Delta\nu_m$	1.6 sec./cm^{-1}	10 sec./cm^{-1}
N (closest * value, Fig. 5.4.4.5)	3/8 RPM	3/32 RPM
T_1 Run time	~ 1 Hr.	~ 1.8 Hr.
τ_d (at N, from Fig. 5.4.4.2)	~ 0.3 sec.	~ 1.2 sec.
Delay (= τ)	1.0 sec.	1.0 sec.
(=(τ/τ_d)0.1)	~ 0.3 cm^{-1}	0.1 cm^{-1}
K/n_m (= $E_p/0.7 \sim 0.1$)	0.1	0.1
n_m (K assumed = 1.0)	10	10
n_u (= $n_m \nu_u/\nu_\ell$) at ν_u	24	19
n_ℓ (= $n_m \nu_\ell/\nu_u$) at ν_ℓ	4	5
Δt_r (=$\Delta t_m/n_m$)	1.0 sec.	1.0 sec.
$\Delta\nu_r$ (= $\Delta t_r/(d\nu/dt)$)	0.6 cm^{-1}	0.1 cm^{-1}
Resol. Setting (closest value)	0.5 cm^{-1}	0.1 cm^{-1}
No. of data points	~ 4200	~ 6500

Note that there are 2n data points in the total slit function width, $2\Delta\nu$. If K had been assumed equal to 2 there would still be 4 to 5 resolution elements in the total slit function width at ν_ℓ. In this case, the resolution setting would be about 1.0 and 0.2 cm^{-1} for the two bands and the number of data points would be reduced by a factor of 2 from those listed above.

The long run times shown above make it clear that the band limits should be reduced as much as possible especially when high resolution is required. For other types of runs the appropriate assumptions may be different from those given above but the general procedure should be the same.

5.4.5 Selective Amplifier Q

For most test conditions a Q of 10 will be found to be satisfactory. Because the selective amplifier takes an increasing time to respond as Q is increased there are operational limits on the Q setting, especially at the faster scanning speeds.

The envelope response of the selective amplifier can be expressed in terms of a decay time constant, $\tau_Q = Q/\pi f$, where Q is the Q control setting and f is the tuned frequency. Using the lower tuned frequency of 330 Hz,

$$\tau_Q = \frac{Q}{\pi(330)} \sim \frac{Q}{1000}$$

or

$$Q = 1000\ \tau_Q$$

If τ_Q is set equal to the lock-in amplifier time constant (see Section 5.4.4), which has a range of 0.01 to 1.0 seconds, the range of Q settings will be from 10 to the maximum Q of 100.

For the fastest scan speeds (for which $\tau = 0.01$ sec. is appropriate) a Q of 10 is satisfactory. A higher Q will cause a more sluggish response. At the lower scan speeds a Q higher than 10 may be used. However, the amplitude and phase response are much more critical with high Q than at low Q.

Figure 5.4.5.1 shows the relative amplitude response of the selective amplifier as a function of Q and (f/f_o) where f is the signal frequency and f_o is the tuned frequency. Since it is difficult to obtain values near f_o from a figure such as this, another plot is shown in Figure 5.4.5.2 which is particularly useful at frequencies near f_o. Figure 5.4.5.2 shows the departure of the response from unity on a log scale as a function of Q and $\Delta f/f_o$ where $\Delta f = |(f - f_o)|$.

The phase response of the selective amplifier is shown in Figure 5.4.5.3 as a function of Q and f/f_o. Note the very large changes in phase near f_o for high values of Q. Changes in the phase can result from drift in either selective amplifier tuned frequency or from drift in the chopper frequency.

One reason for using a Q of 10 in the selective amplifier is that there is a tuned amplifier in the lock-in amplifier reference section with a fixed Q of 10. With a fixed input and equal values of Q a similar drift of the selective amplifier and lock-in reference tuned amplifier frequency will produce no relative phase shift (although an amplitude change occurs in the

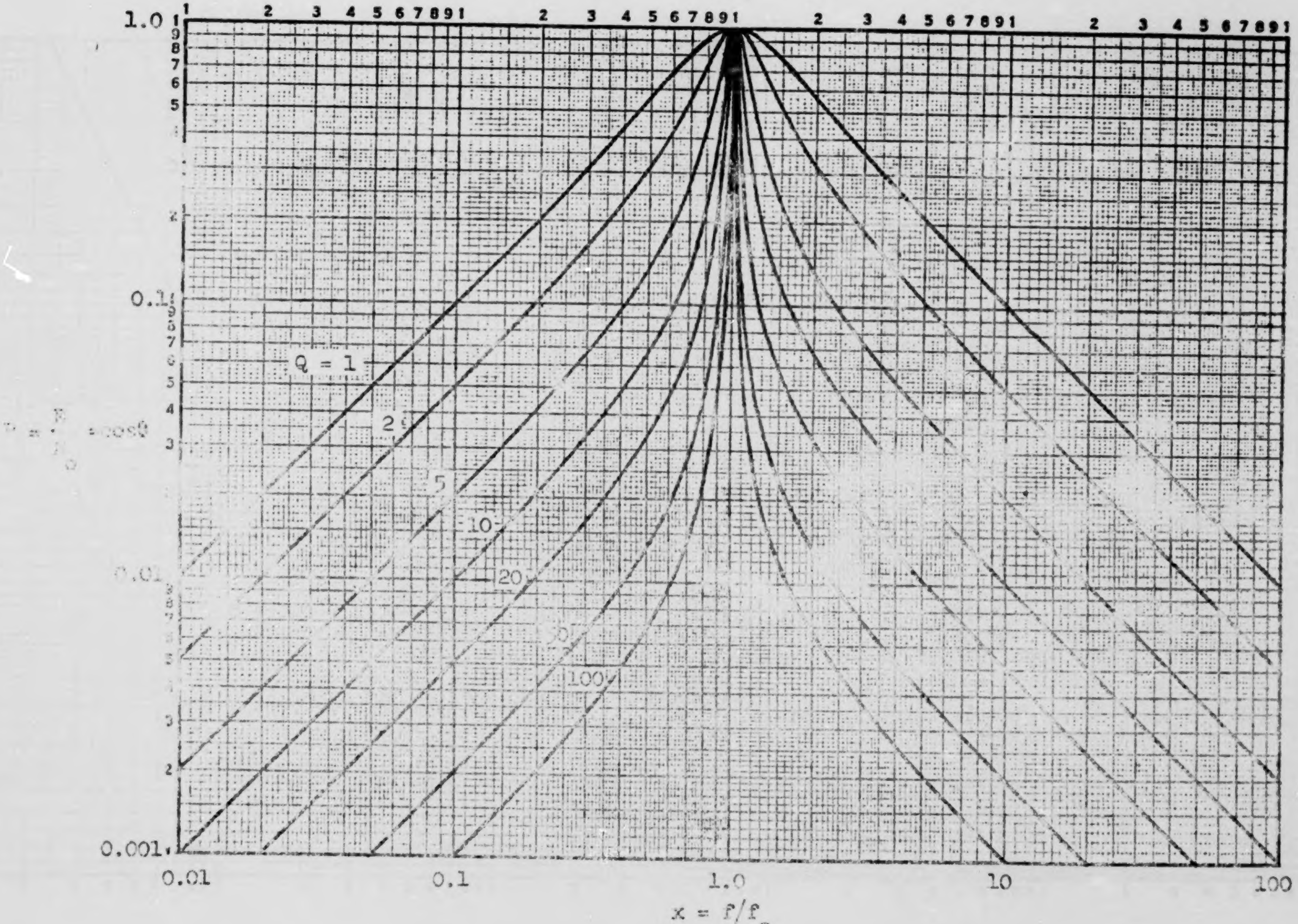


Figure 5.4.5.1 Selective Amplifier Relative Response

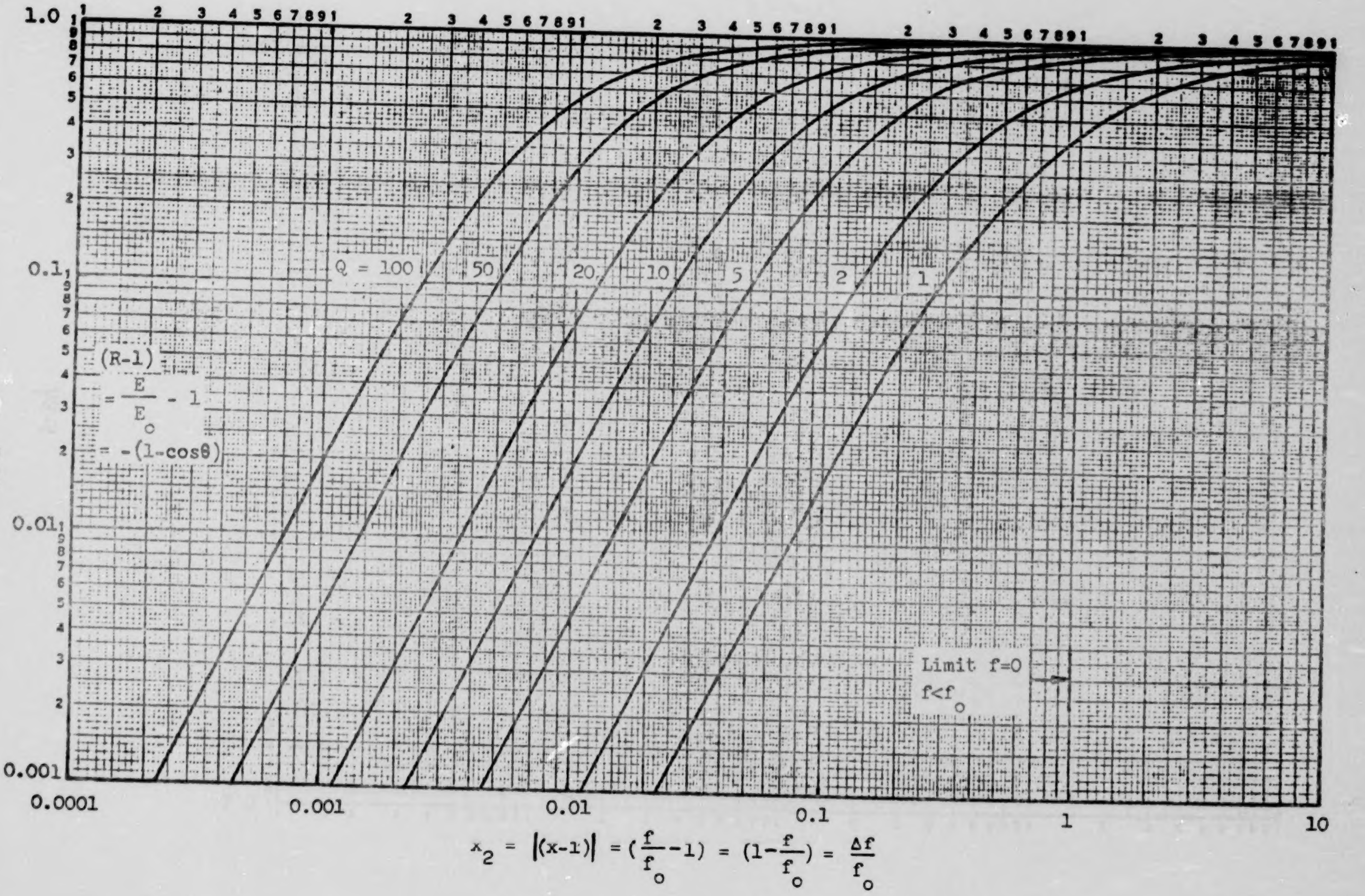


Figure 5.4.5.2 Selective Amplifier Relative Response Near f_o

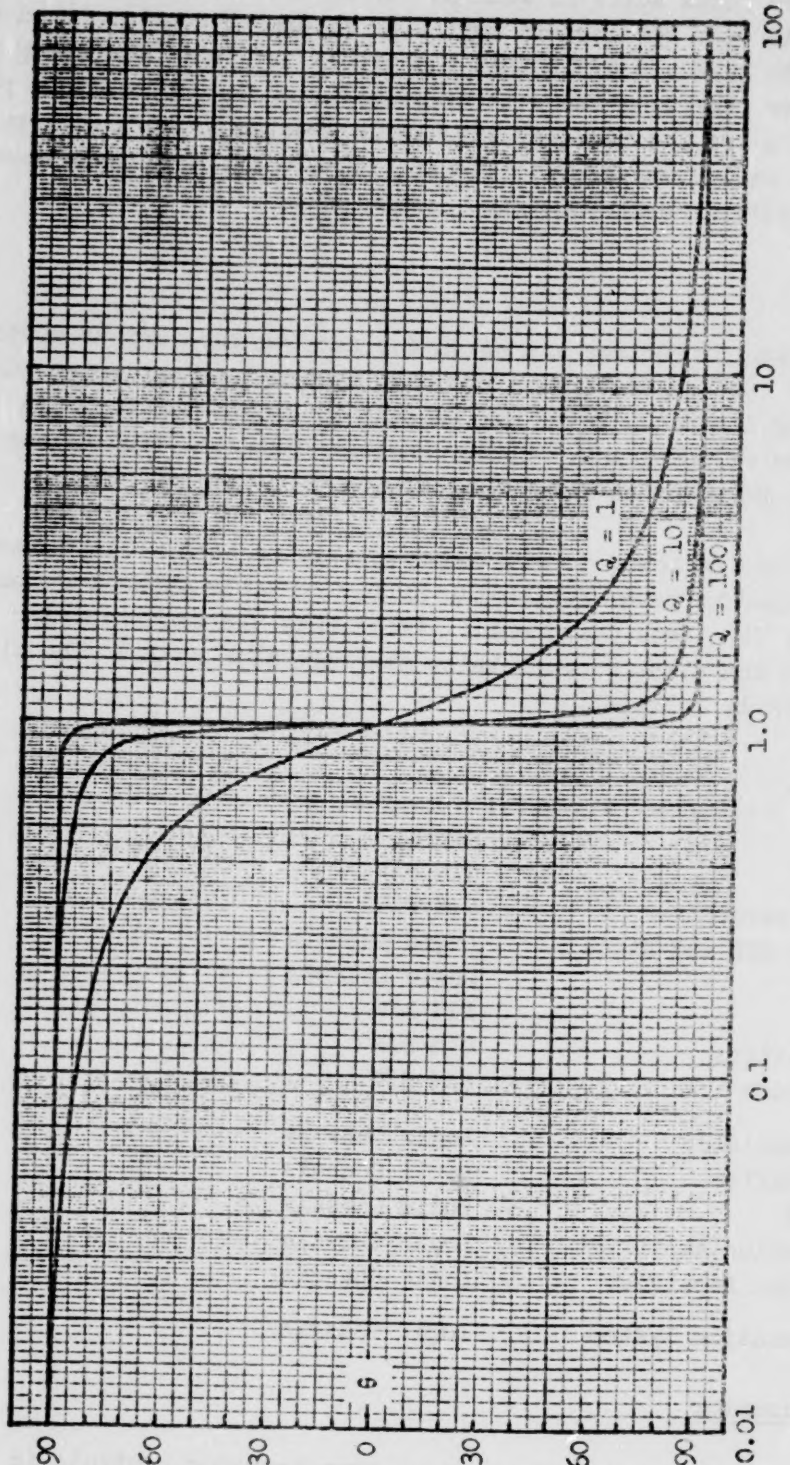


Figure 5.4.5.3 Selective Amplifier Phase Response

selective amplifier, of course). With the selective amplifier $Q \neq 10$ there will be a relative phase shift as well as the amplitude change. If the selective amplifier and the lock-in amplifier reference section tuned amplifier are fixed and both have a Q of 10 then a shift in the input frequency will cause an amplitude change in the selective amplifier but no relative phase shift. If the Q's are not the same this input frequency shift will produce a phase shift as well. Therefore, if possible, a Q of 10 is recommended for the selective amplifier under ordinary conditions.

5.5 PROCEDURE

In this section procedures are given for setting the various controls according to the type of test being run, the chosen test parameters and the type of recording desired. Tests may be made in either the emission or transmission mode of operation. Either analog or digital records may be made independently or both may be made simultaneously.

First, turn on the power to all components to be used. Since some components do not have a separate power switch the following table shows a summary of the sources of power for these components. (Note that the tape recorder power switch is inside the plastic cover below the left tape reel.) The other power switches are clearly labelled.

Sources of Power
(for components not having a separate power switch)

	Source
Detector (bias)	NIM BIN
Source Synch Preamplifier	NIM BIN
Reference Synch LED and Diode	Logic Chassis
Encoder	Logic Chassis
Preamplifier	NIM BIN
Selective Amplifiers	NIM BIN
Lock-in Amplifiers	NIM BIN
Source Synch Amplifier	Logic Chassis
Ref. Synch Amplifier	Logic Chassis
Standard Signal	Logic Chassis
Source Compensation Amplifier	Logic Chassis
Ref. Compensation Amplifier	Logic Chassis
Wavenumber Generation System	Logic Chassis

5.5.1 Monochromator

The procedure for setting the various monochromator controls is given in this section.

The grating is selected according to the wavenumber band being used and the grating in use can be observed through transparent plate under a cover on top of the monochromator. The lid of the monochromator does not have to be removed to change the grating. The round cover be easily removed by simply pulling upward. The grating nearest the paraboloid is the grating in use and L/MM labels have been attached to the grating mount to identify the grating location.

If the desired grating is not in position it can be placed there by rotation of the grating mount. Rotation is accomplished by means of the knob in the center of the transparent plate. The knob controls two prongs which, when the knob is pushed down, engage a pin on the grating mount. While holding the knob down (thereby keeping the pin engaged) gently turn the knob in the direction it will go easily until an abrupt resistance to rotation is felt. Magnets on the grating mount hold it against stops on the grating mount support at the ends of the rotation range. Release the knob and replace the round cover.

The filter associated with each spectral hand may be brought into place in front of the entrance slit by means of a knob on top of the monochromator. The knob actuates a filter wheel in which the filters have been mounted. Besides the two positions for the two spectral bands there are OPEN and SHUT positions of the control knob for which a large hole and a blackened plate respectively are placed in front of the entrance slit.

The width of the entrance and exit slits are equal and may be set by means of a micrometer drum which reads directly in microns. One turn equals 100 microns and the number of turns is marked on the housing. A range of 20 turns gives a maximum slit opening of 2000 microns or 2.0 mm.

The height of the opening at the entrance slit may be set by means of the micrometer control on top of the monochromator. The micrometer reads the slit height directly in millimeters. One turn equals 0.5 mm and the range is from 0 to 12 mm. For the most precise adjustment the micrometer should be set by decreasing the reading.

Wavenumber is set by means of a wavenumber drum on the monochromator. The drum is graduated on an arbitrary linear scale; after set up according to Section 5.5.2 the wavenumber may be read directly on the bidirectional counter in one of the electronic consoles.

The wavenumber drum is divided into 100 divisions per turn and a turns counter (0 to 24 times) is provided. Mechanical stops limit the rotation from a drum reading of about -0.62 (reading = 23.38) to about + 23.73 drum turns. The drum should not be turned hard against these stops or the wavenumber calibration may be affected. Electrical switches in the wavenumber scanning mechanism are set to stop the drive before the mechanical stops are reached.

If the monochromator control panel power is on, the wavenumber drum cannot be turned by hand unless the SPEED CONTROL on the control panel is set to N (for Neutral).

The wavenumber drive turns the wavenumber drum at speeds set by the SPEED CONTROL knob on the monochromator control panel and by ratio gears on the back of the wavenumber drive. Wavenumber drum speeds from 6 RPM to (3/32) RPM in steps of 2:1 ratio are provided. See Section 4.2.7 for more details of the wavenumber drive. Select the proper gear ratio and SPEED CONTROL setting for the speed desired. Normal scanning is in the direction of increasing wavenumber (or drum reading) with the scan direction control switch in the UP position. To start scanning turn on the λ DRIVE switch. If desired, the analog recorder chart can be simultaneously controlled by the λ DRIVE switch by turning on the CHART switch on the monochromator control panel and placing the REMOTE/LOCAL switch on the analog recorder in the REMOTE position.

5.5.2 Wavenumber Generation System

The procedure for setting up the wavenumber generation system is described in this section. (Be sure that the COUNTER X OUTPUT and COUNTER Y OUTPUT terminals on the logic box are connected to the COUNTER INPUT X and COUNTER INPUT Y terminals, respectively, on the electronic console panel beneath the DVM's.

1. Select the 3 to 5.5 micron or 7 to 13.5 micron setting of the BAND SELECTOR on the MODE SELECTOR section of the control panel according to the range being used.

The equations for the wavenumber are posted above the bidirectional counter and are of the form:

Wavenumber = A + B (WD)

2. Set the wavenumber drum to zero
3. Set the MODE switch on the bidirectional counter to CONT.
4. Set the DISPLAY TIME control on the bidirectional counter to MIN.
5. Set the ZERO/SET switch on the bidirectional counter to SET.

6. Set 10(A) on the SET switches of the bidirectional counter (counter reads in 0.1 wavenumber units).

7. Set 10(B) on the COARSE and FINE selectors on the ENCODER CONTROL section of the control panel (again in units of 0.1 wavenumbers) by adding the coarse and fine readings. For B = 52.6, for example, set 500 on the COARSE SELECTOR, 20 on the TENS dial and 6 on the ONES dial of the FINE SELECTOR.

8. Push the RESET button on the bidirectional counter. The number 10(A) should appear in the bidirectional counter window. If the number in the bidirectional counter window does not change on pushing counter RESET, most likely the coupler is generating a hold command. Push the RESET button on the coupler to clear temporarily. To remove the hold place the coupler FUNCTION switch to RECORD ONLY.

9. Run the wavenumber drum up to 1.00 turn and observe that 10(A+B) is displayed in the bidirectional window. Run the wavenumber drum back to zero and observe that 10(A) is again displayed in the bidirectional counter window. Deviations of one or two units are sometimes observed and are normal. (Alternatively, one may place the ZERO/SET switch of the bidirectional counter on ZERO and (with WD = 0) push RESET; the bidirectional counter will then read 10(B) at WD = 1.00 and should return to zero at WD = 0. Reset ZERO/SET switch to SET and set 10(A) as in step 6.)

10. If these readings are observed the wavenumber system is ready for operation.

5.5.3 Amplifiers-Emission

This section contains the procedure for setting up the amplifiers for operation in the emission mode. Be sure the MONITOR output terminal of the reference lock-in amplifier (at the far right) is connected to the SOURCE LOCK-IN INPUT terminal on the control panel (actually the input to the source compensation amplifier).

It is assumed that the system has been set up and started as described in Section 5.2 and 5.3, that the test parameters have, at least, been tentatively selected as indicated in Section 5.4 and that the wavenumber generation system has been set up as given in Section 5.5.2.

1. Set the OPERATE/STD SIG. switch on the control panel to STD SIG

2. Lock-in amplifier

   a. Set the METER/MON switch to the REF position.

   b. Set the TIME CONSTANT to 0.1 sec.

   c. Tune the FREQUENCY control to maximize the meter (about 330 Hz) reading. A reading of about 0.80 of full scale should be observed on the lock in amplifier meter with a normal setting of the REFERENCE LEVEL control.

3. **Selective Amplifier**

   a. Set the gain to X10

   b. Temporarily set the Q control to 100 to make tuning more precise.

   c. Set STD. SIG τ ADJUST to full scale (=1000)

   d. Set the FREQUENCY control on the selective amplifier to give a maximum reading on the lock-in amplifier meter

   e. Set the Q control to the test value

   f. Set the GAIN control to X1.

4. Set the wavenumber to a large signal region and open the slits test value. Previous SYSTEM OPERATING LOG settings will be helpful. The slits may be temporarily widened until a signal is observed and initial settings made.

5. Preamplifier

   a. Set the lock-in amplifier GAIN to 10

   b. Set the OPERATE/STD SIG switch to OPERATE

   c. Set the preamplifier GAIN as high as possible without overloading the selective amplifier or lock-in amplifier

6. Lock-in Amplifier

   a. Set the METER/MON switch to PSDX1 (phase sensitive detecting X1 meter)

   b. Adjust the PHASE switch and dial to give a maximum meter reading. If the meter goes off scale decrease the preamplifier GAIN and repeat the phase adjustment.

7. Decrease the monochromator slits to the test value

   a. Readjust the preamplifier GAIN to obtain a half scale to full scale lock-in meter reading. If necessary, increase the selective amplifier GAIN to 10X and, if further required, increase the lock-in amplifier GAIN.

8. Lock-in Amplifier

   a. Scan the monochromator slowly by hand over the spectral region of interest and find the maximum positive meter reading. Note the reading.

   b. Repeat step a except for the maximum negative reading. If the meter goes below zero, switch on the ZERO SUPP switch and adjust the ZERO SUPP dial to keep the signal above zero.

c. Recheck a. and reduce the preamplifier gain if necessary to keep the maximum positive signal on scale.

d. The entire signal range should now be within the limits of zero and full scale of the lock-in meter.

e. Set the lock-in amplifier TIME CONSTANT to the value desired in the test.

9. Data Acquisition System

a. Set τ_{sig} to 125 (1000 full scale)

b. Turn the 5403-010 DVM FUNCTION switch to VOLTS and the RANGE switch to 10

c. Plug INPUT of the 5403-010 DVM into the SOURCE COMP OUT terminal of the control panel.

Observe the voltage on the DVM at the wavelengths for the maximum negative and maximum positive signals to see that the signals remain positive on the DVM and are less than 10 volts.

d. Set the RESOLUTION SELECTOR to the desired resolution for the digital system.

10. Optical Zero

a. Place the filter wheel at the monochromator entrance slit in the SHUT position

b. Observe the DVM and lock-in meter reading for optical zero.

11. A check scan can be made on the analog recorder if desired.

a. To record the spectrum set the analog recorder input selector to I. The recorder is connected to the source compensation amplifier output. Set the recorder to an appropriate scale and speed and scan the spectrum (see Section 5.5.6).

12. System Operating Log

a. Make a complete record in the SYSTEM OPERATING LOG for each run.

5.5.4 Amplifiers-Transmission

This section contains the procedure for setting up the amplifier for operation in the transmission mode. Be sure the MONITOR output terminal of the reference lock-in amplifier is connected to the REF LOCK-IN INPUT terminal on the control panel and the MONITOR output terminal of the source lock-in amplifier is connected to the SOURCE LOCK-IN INPUT terminal on the control panel. (as noted before, these terminals designated LOCK-IN INPUT are, in fact, inputs to the compensation amplifiers).

It is assumed that the system has been set up and started as described in Section 5.2 and 5.3, that the test parameters are known (Section 5.4), and that the wavenumber generation system has been set up as described in Section 5.5.2.

1. Set the OPERATE/STD SIG switch on the control panel to STD SIG
2. Lock-in Amplifiers
   a. Set the METER MON switch of both lock-in amplifiers to REF
   b. Set the TIME CONSTANT of both lock-in amplifiers to 0.1 sec
   c. Tune the FREQUENCY control of the source lock in to maximize its meter reading (about 570 Hz).
   d. Tune the FREQUENCY control of the reference lock-in amplifier to maximize its meter reading (about 330 Hz). (These readings c. and d. are normally about 0.8 of full scale with the normal setting of the REFERENCE LEVEL control.)
   e. Set both lock-in GAIN controls to 10.
   f. Set the METER/MON switch of both lock-in amplifiers to SIG
3. Selective Amplifier
   a. Set the gain to X10
   b. Temporarily set the Q control of both selection amplifiers to 100 to make tuning more precise.
   c. Set STD SIG τ ADJUST to full scale(=1000). Note: If only the reference chopper is being used, set STD SIG τ ADJUST to zero to reduce noise from unused source channel.
   d. Set the FREQUENCY control on both selective amplifiers to maximize the corresponding lock-in amplifier meter reading.
   e. Set the Q control of both selective amplifiers to the test value.
   f. Set the GAIN control of both selective amplifiers to X1.
4. Set the wavenumber to that for the peak signal for the wavenumber interval being used and open the slits to the test value. (Previous SYSTEM OPERATING LOG settings will be helpful.) The slits may be temporarily widened until a signal is observed and initial settings are made.
5. Preamplifier
   a. Set each lock-in amplifier GAIN to 10.
   b. Set the OPERATE/STD SIG switch to OPERATE.
   c. Set the preamplifier GAIN as high as possible without overloading the selective amplifiers or lock-in amplifier.

6. Lock-In Amplifiers (Reference Balance Procedure)

   a. Set the METER/MON switch of both lock-in amplifiers to PSD x 1 (phase sensitive detector; X/meter) Be sure the ZERO SUPP switch of both lock in amplifiers is at OFF.

   b. Block the reference beam at the intermediate focus with a blackened plate.

   c. Adjust the PHASE switch and dial of each lock-in amplifier to maximize the lock-in meter reading.

   d. Readjust the preamplifier gain, if necessary, to give a meter reading of about half scale to full scale.

   e. Connect the INPUT of the 5403-010 DVM to the REF COMP AMP OUTPUT terminal on the control panel. Set the DVM FUNCTION switch to VOLTS and the RANGE switch to 10.

   f. Adjust the reference lock-in GAIN ADJ control until the DVM reading is a minimum (a few millivolts).

   g. Remote the reference beam block and observe the DVM reading. The ref lock-in meter will go off scale negative; this is normal.

   h. Block the source beam between the telescope and the reference chopper and observe the DVM reading.

   i. The readings from g. and h. should be equal within about 1% of the reading or less. If not go to step b. and go through the reference balance procedure again.

   j. If the gains of the selective amplifiers or lock-in amplifiers are changed the reference balance procedure should be repeated. The GAIN and Q settings of the reference selective amplifier should always equal the GAIN and Q settings of the source selective amplifier. The GAIN and TIME CONSTANT settings of the reference lock-in amplifier should always equal those of the source lock-in amplifier.

7. Scan through the spectral region to be sure the source and reference signals do not go off scale.

8. Select and set the wavenumber region to be assigned a known or arbitrary relative transmission.

9. Be sure the INPUT of both DVM's are connected to the SOURCE COMP AMP OUTPUT.

10. Connect the DVM RATIO INPUT below the 5403-010 DVM to the REF COMP AMP OUTPUT.

11. Set the FUNCTION switch of the 5403-010 DVM to 10X RATIO.

12. Set the known or arbitrary relative transmission on the 5403-010 DVM by means of the τ_{sig} control.

13. Check scans can be made on the analog recorder if desired.

    a. To record I, set the analog recorder input selector to I. The recorder is connected to the source compensation amplifier output. Set the records to an appropriate scale and speed and scan the spectrum (see Section 5.5.6).

    b. To record I_o, set the analog recorder input selector to I_o. The recorder is connected to the reference compensation amplifier output. Set the recorder to an appropriate scale and speed and scan the spectrum (see Section 5.5.6).

    c. To record I/I_o set the analog recorder selector switch to I/I_o. The recorder is connected to the output of the I/I_o ratio module. Set the recorder to an appropriate scale (I/I_o = 1.0 gives 1.00 volt to the recorder) and speed and scan the spectrum (see Section 5.5.6).

14. System Operating Log

    a. Make a complete record in the SYSTEM OPERATING LOG for each run.

5.5.5 Data Recording Systems

The procedures for setting up and using the recording systems are described in this section. The two systems (analog and digital) are described separately since they may be operated independently.

Analog Recording System

The procedure for operating the analog recorder itself is virtually identical to that described in the Hewlett Packard 7701A and preamplifier 8801A manuals. The basic procedure is given here. Refer to these manuals for more details. Those features of operation unique to the ROSE system are discussed below.

The inputs to the recorder pass through an input selector switch located just to the left of the recorder. This switch has three positions by means of which the recorder input is connected to the following:

Position	Voltage	Source
I	~10V max	Source Comp. Ampl. Output
I_o	~10V max	Ref Comp. Ampl. Output
I/I_o	~1V max	I/I_o Ratio Module

It should be noted that the I/I_o ratio module has a negative voltage output. In order for the recorder to read up scale in the normal manner the leads to the recorder have been reversed and both leads must float with respect to ground.

The REMOTE/LOCAL switch is connected so that, in the REMOTE position, the recorder will run (if the CHART switch on the monochromator control is ON) whenever the λ DRIVE switch is turned on.

It is emphasized that great care should be used in replacing the chart paper not to bend the galvonometer or event marker arms.

The following procedure should be used to set up for analog recording.

1. Set up the wavenumber generation system as discussed in Section 5.5.2.
2. Attach the pushbutton switch on a cord to the MANUAL INPUT jack on the recorder panel to the left of the analog recorder.
3. Set the input selector switch to the desired position: I, I_o or I/I_o.
4. Set the REMOTE/LOCAL switch to REMOTE (and CHART switch on monochromator control to ON) for simultaneous records chart and scan drive operation. (Set the REMOTE/LOCAL switch to LOCAL for independent analog recorder operation).
5. Select the recorder chart speed by selecting MM/SEC or MM/MIN and pushing one of the numbered pushbuttons.
6. Select the V/DIV range (I & I_o are 10 V max; $I/I_o \sim 1.0$V max). The chart is 50 divisions wide.
7. Push the red button in the center of the V/DIV switch to connect the analog recorder to the source.

Digital Recording System

The following procedure is to be used to set up the digital recording system.

1. Bidirectional Counter
   a. Set the FUNCTION switch to (X-Y) and the NORMAL/REVERSE switch to NORMAL.
   b. Set the LIMIT thumbwheel switches to +99999.
   c. Set the MODE switch to CONT. and the DISPLAY TIME switch to MIN.
   d. At the rear: set FAST/NORMAL switch to FAST. X1/X2/X4 may be in any position.
2. 5403-015 DVM (upper)
   a. Set the READ/HOLD switch to HOLD.
3. 5403-010 DVM (lower)
   a. Set the READ/HOLD switch to HOLD.
   b. Set the FUNCTION switch to 10X RATIO.

4. Digital Printer

   a. Be sure there is sufficient paper in the printer (system will halt if paper runs out).

   b. Press OPER button (operate).

   c. At the rear: A1J1 switch should be down; A1J2 switch up.

5. Digital Coupler

   a. Set the OPERATE/STANDBY switch to STANDBY.

6. Tape Recorder

   a. Load tape into the tape recorder.

   (a tape threading diagram is located on the inside of the recorder cover.

   b. Press LOAD FORWARD. Tape should feed into the recorder until a silvery patch stops near the large head and the READY light on the tape recorder should come on. The TAPE NOT READY light on the coupler should extinguish.

7. Press the RESET button on the coupler to extinguish the coupler WRITE ERROR light.

8. Press the tape recorder FILE GAP button.

The digital system is now ready for the first run; see Section 5.5.6 for procedure in scanning a spectrum.

5.5.6 Scanning the Spectrum

The prcedure to be used depends on the method of recording to be employed. It is not necessary to set up the digital recording system if only the analog records are to be made. The procedures for each type of recording is given in the following sections. If both analog and digital recordings are to be made, set up both the analog and digital system as indicated in Section 5.5.5. All of the procedures in the Analog Recording Procedure below except step 6 are also in the Digital Recording Procedure. That step should be added to the digital procedure if both types of recordings are to be made.

Analog Recording

It is assumed that the Wavenumber Generation System has been set up (see Section 5.5.2) and the Analog Recording System procedures have been followed (see Section 5.5.5).

1. Set the monochromator SPEED CONTROL to N.

2. Set the wavenumber drum of the monochromator to the lower wavenumber limit of the region of interest.

3. Set the SCAN UP/DN switch on the side of the wavenumber drive to UP.

4. Set the monochromator SPEED CONTROL to S1, S2 or S4 depending on the scan speed desired. Consult the chart on top of the wavenumber drive for the available speed (see also Sections 4.2.7 and 5.5.1.). Change ratio gears if necessary to obtain the desired speed.

5. Turn the λ DRIVE switch ON. This starts the scan and analog recorder.

6. For automatic marker operation place the MARKER SELECTOR switch to AUTO; set the marker $\Delta\nu$ to 1, 10 or 100 cm^{-1} as desired.

   For manual marker operation place the MARKER SELECTOR switch to MANUAL; watch the wavenumber display on the bidirectional counter and push the event marker pushbutton at desired intervals.

7. Turn the λ DRIVE switch OFF when the upper limit of the wavenumber region is reached. (Be sure to do this; putting the SPEED CONTROL at N will also stop the scan drive but the recorder will continue to run.)

8. Record the operating parameters in the SYSTEM OPERATING LOG and the run number on the chart record.

9. Go to step 1 for the next run.

Digital Recording

It is assumed that the Wavenumber Generation System has been set up (see Section 5.5.2) and the Digital RecordingSystem set up procedures have been followed (see Section 5.5.5).

1. Set the monochromator SPEED CONTROL to N.

2. Select PRINT ONLY, PRINT & RECORD or RECORD ONLY on the FUNCTION switch of the data coupler.

3. Set the RESOLUTION SELECTOR ON THE ENCODER CONTROL section of the control panel to the desired resolution (compatible with the scan speed). If the RESOLUTION SELECTOR is set at OFF the digital system will not operate.

4. Load the counter SET thumbwheel switches with the run I.D. number.

5. Press RESET on the counter.

6. Press MAN SPACE on the digital printer 4 times (if the printer is being used).

7. Record the run I.D. number by setting the coupler OPERATE/STANDBY switch to OPERATE and pressing START on the data coupler 4 times. Set coupler OPERATE/STANDBY switch to STANDBY.

8. If it is desired to check the operation on RECORD ONLY the digital printer may be used by pushing MAN PRINT; the run I.D. appears at the right on the paper.

9. Press MAN SPACE on the digital printer (if the printer is being used).
10. Press FILE GAP on tape recorder (if the tape recorder is being used).
11. Reset the SET thumbwheel switches on the counter to the 10(A) value for the spectral band being used.
12. Set the monochromator drum to zero.
13. Push RESET on the counter; if 10(A) does not appear in the counter window push RESET on the coupler.
14. Set the wavenumber drum of the monochromator to the lower wavenumber limit of the region of interest.
15. Set the SCAN UP/DN switch on the side of the wavenumber drive to UP.
16. Set the monochromator SPEED CONTROL to S1, S2 or S4 depending on the scan speed desired. Change ratio gears if necessary.
17. Set the coupler OPERATE/STANDBY switch to OPERATE.
18. Turn the λ DRIVE on. This starts the scan and the recording system. The printer, if selected, will start printing. The tape recorder, if selected, will move slightly with each record.
19. Turn the λ DRIVE switch OFF when the upper limit of the wavenumber region is reached.
20. Set the coupler OPERATE/STANDBY switch to STANDBY.
21. Press FILE GAP on the tape recorder (if the tape recorder is being used).
22. Record the operating parameters in the SYSTEM OPERATING LOG.
23. Go to step 1 for the next run.

5.6 System Shut Down

Most of the equipment power can be turned off at any time but several components should be turned off in a prescribed manner as described in this section.

5.6.1 Blackbodies

Use the following shut down procedure (based on the blackbody manufacturer's recommendations) when the blackbody is not going to be used for a day or so.

1. Record the time, dial setting and controller meter reading in the BLACKBODY OPERATING LOG.
2. Turn off temperature controller power.
3. Wait one hour.
4. Turn off blackbody cooler power.

If the blackbody is to be used again within 12 to 24 hours or so, use the following procedure.

1. Record the time, dial settingand controller meter reading in the BLACKBODY OPERATING LOG.
2. Turn the dial on the temperature controller down to 500.
3. Leave the cooler running.

The manufacturer states that turning off the cooler when the temperature controller is turned off should not cause a catastrophic failure (now that the internal plastic hoses have been replaced by copper) but that such a procedure is not recommended.

If the blackbody is left on stand-by at the 500 dial setting it would be wise to have the temperature controller and cooler on the same 110V power source. In that case, a power failure would cut off the temperature controller as well as the cooler.

5.6.2 Detector Cooler

Use the following procedure for detector cooler shut down.

1. Record the cooler compressor SUCTION PRESSURE, OIL LEVEL and TIME readings in the DETECTOR COOLER OPERATING LOG.
2. Record the hydrogen gage pressure, PSIA, and Dewar PRESSURE reading from the thermocouple gage control in the DETECTOR COOLER OPERATING LOG.
3. Turn off the detector cooler compressor.
4. When the Dewar PRESSURE reading exceeds about 20 microns or so turn on the vacuum pump and, after a few minutes, open the Dewar valve. This will ensure that any condensate on the cold finger from even small leakage over protracted periods will not evaporate and build up pressure in the Dewar.
5. If the detector cooler is not going to be used the next day or so, wait until cold finger has warmed about 3 hours; close the Dewar valve and shut off the vacuum pump. If the detector cooler is to be used again in the next 12 to 24 hours it is preferable to leave the vacuum pump on to ensure that the Dewar is pumped out thoroughly.

6.0 PERFORMANCE

The performance of the ROSE system described in this section is limited to laboratory tests and initial field tests at a range of about 0.4 km in San Diego. The performance is described in terms of the expected vs observed signal and noise. The performance in the field at longer ranges (particularly with regard to the spectroscopic performance) will be described in a forthcoming field test report.

6.1 LABORATORY TESTS

A number of laboratory tests of various parts of the system as well as tests of the system as a whole have been made. Many of these were made for functional checkout and will not be described here. Rather, emphasis here is on the expected versus observed signal and noise of the system as a whole. In addition, typical spectra obtained under laboratory conditions will also be described.

6.1.1 Signal

The best place in the system to compare the expected versus observed signal is at the source lock-in amplifier output. During the tests described here (as well as in the field tests) the analog recorder (with the selector switch in the I position) was connected to the source lock-in amplifier output. It is now connected to the source compensation amplifier output to facilitate emission mode measurements; future measurements equivalent to those described here can be made by placing the analog recorder input selector switch in the I position and setting the "τ sig" control to 125 (1000 full scale). This τ sig setting combined with a gain of 8.0 in the source compensation amplifier gives an overall gain of 1.00 between the source lock-in amplifier output and the source compensation amplifier output.

First of all, it was established that the preamplifier gain could be taken equal to the nominal gain and the selective amplifier and lock-in amplifier were calibrated as described in this report.

With the source blackbody at its normal setting corresponding to 1800K and both choppers running, observations were made of the I signal for each grating and its corresponding filter for the following conditions (corresponding to $\Delta\lambda \sim 0.01$ microns).

ν	Slit	Deflection	V/Div	S_{xs}
2500 cm^{-1}	700 µ × 2.7 mm	22	0.04	0.88 volts
"	700 µ × 0.27 mm	23.5	"	0.94
1000 cm^{-1}	300 µ × 2.7	9	"	0.36
"	300 µ × 0.27 mm	9	"	0.36

These conditions were set up to give roughly the flux expected at simulated ranges of 0.4 and 4.0 km with $h/h_o = 1.0$. These spectral regions should be reasonably free of absorption for the conditions reported here.

The calculation of the expected signal is based on the equation for S_{xs} given in the Radiometry Section 3.3.1.

$$S_{xs} = R_d \tau_c A\Omega_c \Delta\lambda \left\{ \frac{\left[N_s^o(\lambda, T_s) - N_w^o(\lambda, T_w) \right] (1-\alpha) \rho^4 (A\Omega_t / A\Omega_c) M_1}{2\sqrt{2}} \right\} G \quad .$$

In this equation, several factors may be neglected. $N_w^o(\lambda, T_w)$ for a source choppper temperature of 300K is negligible compared to $N_s^o(\lambda, T_s)$ for the 1800K source. The absorption α is taken equal to zero in the laboratory and the factor $(A\Omega_t/A\Omega_c)$ is taken equal to 1.00 since h/h_o and s/h_o in the laboratory are very nearly zero.

The other factors are calculated as described in the Radiometry Section and are listed below.

ν	Slit	R_d	$\tau_c \rho^4$	$A\Omega_c$	$\Delta\lambda$	$N_s(\lambda, T_s)$
2500	700 µ × 2.7mm	0.5×10^5 V/W	.11	3.5×10^{-4} cm^2ster	0.0101µ	1.83*
2500	700 µ × 0.27	"	"	0.35×10^{-4}	"	"
1000	300 µ × 2.7	1.2×10^5 V/W	.13	1.5×10^{-4}	0.0107µ	0.097
1000	300 µ × 0.27	"	"	0.15×10^{-4}	"	"

*watts/cm^2sterµ

These factors when combined with the modulation factor $M_1 = 0.63$ and the gain used in the observations give the following expected signals and values of observed to expected signal ratio.

ν	Slit	$G = G_p \times G_{fs} \times G_{xs}$	Expected S_{xs}	Ratio $\frac{obs}{exp}$
2500	700 µ × 2.7 mm	200 = 10 × 1 × 20	1.60	0.55
"	700 µ × 0.27	2,000 = 100 × 1 × 20	1.60	0.58
1000	300 µ × 2.7	1,000 = 50 × 1 × 20	0.54	0.67
"	300 µ × 0.27	10,000 = 500 × 1 × 20	0.54	0.67

The largest uncertainty in the expected signal estimate lies in the transmission factor; e.g., the reflectivity of aluminized surfaces enters as ρ^{12} in the transmission mode of operation. However, other factors undoubtedly contribute to the uncertainty including aberrations and possible misalignment. However, all alignments have been made with care. Aberrations for these slit widths and heights would not be expected to contribute a large factor.

From these considerations, the observed signal is less than that expected by a factor of 1.5 to 1.8.

6.1.2 Noise

Noise data taken at the same gain as the last run listed above, namely, 10^4, and with a time constant of 0.01 sec showed peak to peak deflections of 3 divisions which corresponds to 0.12 volts pp at the source lock-in amplifier output. This results in an observed signal to peak to peak noise ratio of about 3 for this fast scan simulation of long range conditions. By scanning at the minimum speed and with a time constant of 1.0 second, a signal to noise ratio of about 30 would be expected based on peak to peak noise. Tests at $G = 10^5$ and $\tau = 0.01$ second gave a noise voltage of 2 volts peak to peak on the recorder (see Section 4.1.6) which is equivalent to 0.20 volts pp for the gain used here.

Noise tests showed that the electronic signal amplification system will not degrade the noise for reasonable gains. With a Q of 100 ($t_Q \sim 0.1$ second) and a lock-in amplifier time constant of 0.01 second the thermal noise of a precision 10% resistor was observed at a gain of 10^6 but not at 10^5. Operational gains are substantially less than this, and the 10K thermal noise is only about 1% of the detector noise.

Calculation of the expected noise for the above test conditions of 10^4 gain and 0.01 second time constant ($\Delta f = \frac{1}{4}\tau$ = 25 Hz) using the detector noise, $V_n/\sqrt{Hz}$ = 0.8 microvolts rms, gives an expected output of $(0.8 \times 10^{-6})(5)(10^4)$ = 0.04 volts if the noise were a constant synchronous signal. Of course, the long term average lock-in amplifier output resonse to noise is zero but the short term average varies from zero. If the noise were to be alternately in and out of phase with the reference signal a peak to peak output of 0.08 volts would be the result of a constant input of 4 microvolts rms. Since the noise has a random amplitude the variation of the output should exceed this value. If the above rms value is associated with the standard deviation, σ, of a normal distribution then deviations of about 3σ (or 0.24 volts peak to peak) should occur less than 1% of the time. Thus, the observed noise of 0.12 t 0.2 volts peak to peak is not inconsistent with that associated with the detector noise alone. It is difficult, at this point, to define more precisely the peak to peak noise indication on the analog recorder in terms of the rms noise at the detector. Therefore, noise comparisons will be made in terms of peak to peak recorder indication taking 0.16 V pp as that corresponding to detector noise.

6.1.3 Typical Scans

A number of traces including those for which the data is given above are shown in Figure 6.1.3.1.

A portion of a wavelength CO calibration scan is shown in Figure 6.1.3.2. The central line is the R5 line which is one of the stronger lines of the band. The spectral width of the output of 0.9 cm^{-1} is about that expected from the spectral slit width of 0.71 cm^{-1} plus the full width at half height of the absorptivity curve of about 0.28 cm^{-1} or a total of about 1.0 cm^{-1}. The wavenumber indicated by the linear wavenumber drive was within 0.2 cm of the value given by Plyler et al., in NBS Research 64 (1960). Note that the resolution here is equivalent to about 0.002 microns, well below the specified value of 0.01 microns.

Another scan shown on Figure 6.1.3.3 is that for ozone produced by a generator and loaded into a cell which was placed between the source and receiver telescopes.

6.2 FIELD TESTS

The field tests at a range of about 0.4 km in San Diego included tests made with the identical conditions as those in the laboratory described above

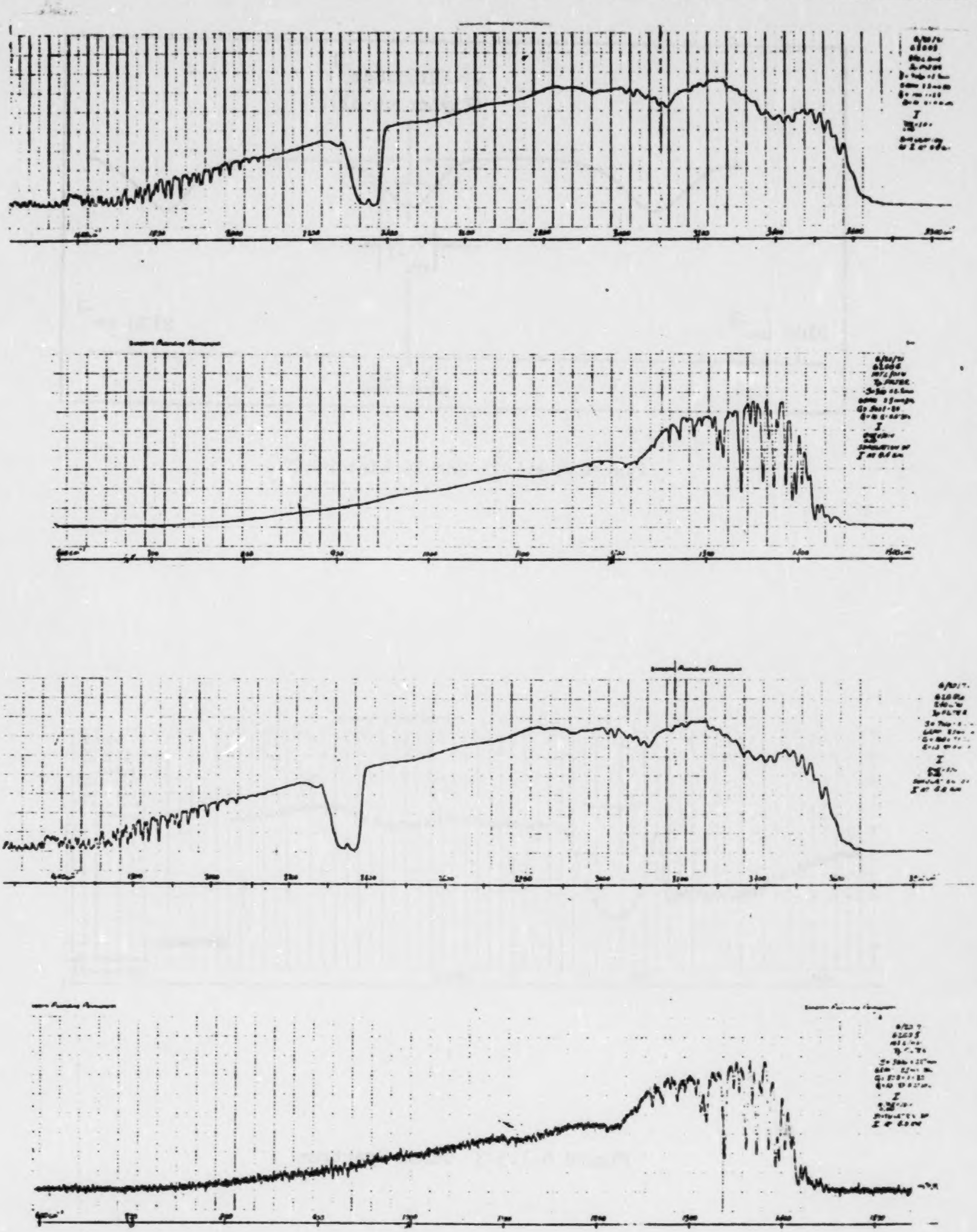


Figure 6.1.3.1 Typical Laboratory Scans

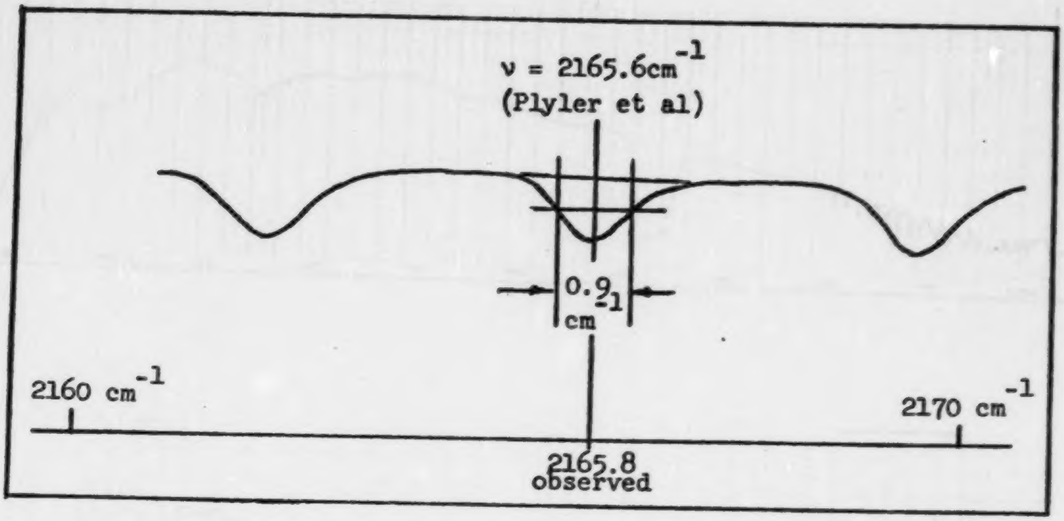


Figure 6.1.3.2 The R5 Line of CO

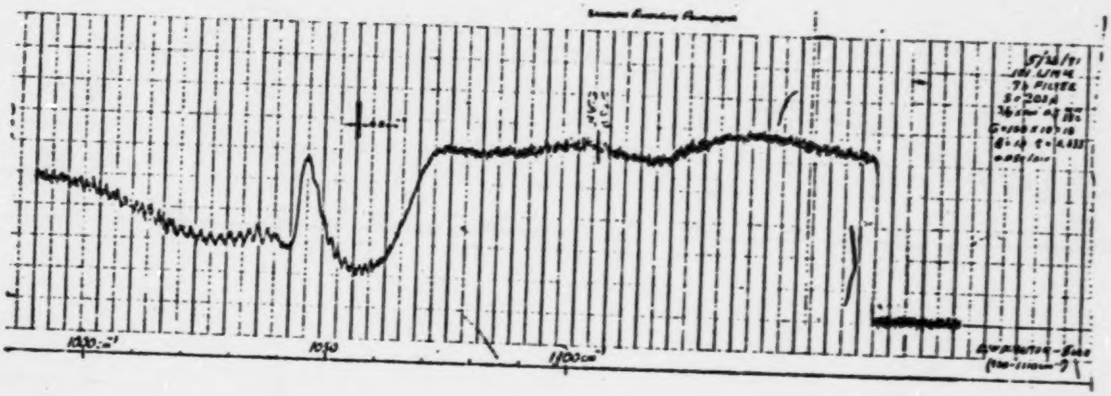


Figure 6.1.3.3 Ozone Spectrum

except for the vignetting factor resulting from the range. Again, signal and noise observations are to be compared to the expected results.

6.2.1 Signal

Data for the San Diego field tests with the same conditions of slit height and width setting, time constant, gain, Q, etc., as those used in the laboratory tests are shown below.

ν	Slit	Deflection	V/Div	S_{xs}
2500 cm^{-1}	700 μ × 2.7 mm	16.2	0.04	0.65 volts
1000 cm^{-1}	300 μ × 2.7 mm	6.5	"	0.26

The relative vignetting factor $(A\Omega_t/A\Omega_c)$ for the field test conditions, (h_o = 9.3 mm), are as shown below. The signal would be expected to be reduced relative to the laboratory measurements by this ratio.

ν	$A\Omega_t/A\Omega_c$	S_{xs} Lab	Expected S_{xs}
2500 cm^{-1}	.68	0.88 volts	0.60 volts
1000 cm^{-1}	.70	0.36	0.25

Thus, the observed field signals agree with those expected on the basis of the laboratory measurements.

6.2.2 Noise

In general, two types of noise were observed: the zero line (presumably electronic) noise and the noise associated with a signal. In some cases the two values of noise were virtually equal and in other cases the signal noise was substantially higher than the zero line noise.

An evaluation of the zero line noise was made by normalizing the observed noise at the source lock-in amplifier output to the same gain and time constant as that used in the laboratory tests, i.e., $G = 10^4$ and $\tau = 0.01$ seconds. Data were taken either with the source beam blocked, at regions where the filter cuts off or in regions where the flux is very low.

$$V_{n\ eq.} = V_{n\ obs.}\left(\frac{10^4}{G}\right)\sqrt{\frac{\tau}{0.01}}\quad .$$

The average value of $V_{n\ eq.}$ was about 0.3 to 0.4 volts peak to peak which is about 2 times that observed in the laboratory.

No clear cut reason for this increase over the laboratory value is known. Both the field and laboratory tests were made using commercial line power. The field test site was at times, rather windy, but no direct effect of the wind on the zero line noise would be expected, except perhaps from cable motion. It is curious that the zero line noise appeared to be a minimum at about sunset (approaching the laboratory value).

The noise on the signal varied roughly with the signal indicating that atmospheric refraction was the cause. During daylight hours with a large slit width, this signal noise was substantially above the zero noise. Near sunset with small slits the signal noise was much reduced. After dark with even smaller slits the signal and zero line noise were approximately equal. For the conditions of this test the signal noise became noticeably larger than the zero line noise for slit widths greater than about 300 microns. The increased signal noise limits the signal to noise ratio for the larger slit widths.

The signal noise on the I/I_o trace was more than that on the I trace, the ratio being, in several instances, about twice that of the I trace. This probably comes about partly because of the noise contribution of both I and I_o (although the I_o signal noise is less than that of the I signal) and partly because of a noise contribution of the I/I_o module for these signal levels. The latter source of noise is reduced in the present instrument because larger signals can now be used. At the time of these tests an overload condition in the source compensation amplifier required low signal levels; this condition has been corrected.

The tests described here were all run at a slit height of 2.7 mm for comparison with laboratory data. It is believed that less signal noise may be obtained with larger values of h, say $h \sim h_o = 9.3$ mm at 0.4 km, or even more. Tests are planned to investigate the variation of signal noise with h/h_o. In any case, signal noise will set a signal to noise limit for wide slit widths; the question remains at what level of signal to noise. This will probably be an individual characteristic of each test site which may vary even over the course of time during a day's testing.

The variations of atmospheric refraction which produce signal noise are a property of the atmospheric path. Preliminary indications are that the instrument response to these variations can be reduced for $h_o < 12$ mm, by using a slit height greater than h_o. (Note, however, that $h = h_o$ should still be used for calculating the flux in this case.) At the longest ranges where h_o is about 1 mm, the use of a 12 mm slit height would permit a considerable vertical image motion from atmospheric refraction with little signal noise increase.

6.2.3 Typical Scans

Several typical scans made during the San Diego field tests are shown on Figure 6.2.3.1.

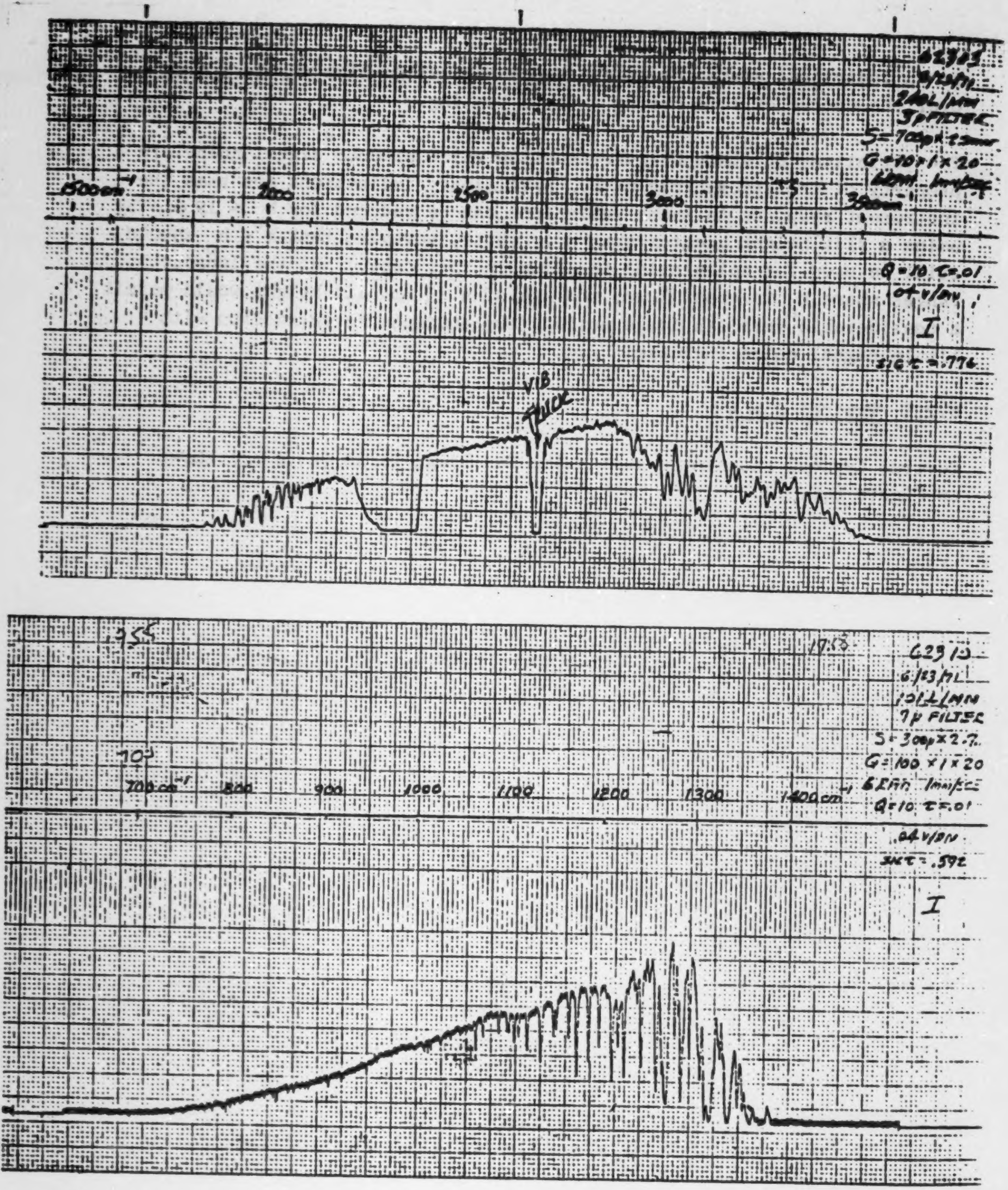


Figure 6.2.3.1 Typical Field Test Scans

7.0 MAINTENANCE

Most of the vendor provided equipment items in the ROSE system are described in the manuals included as part of the system. No effort is made to collect the trouble shooting and maintenance sections of all these manuals here; rather, these manuals should be consulted individually if trouble should develop in a particular vendor component.

The main thrust of the discussion in this section is the trouble shooting and maintenance of Convair built components and vendor components for which manuals are not provided. For convenience, those items for which manuals are provided are included with a notation of that fact.

The components are divided into optical, mechanical, and electrical groups.

7.1 OPTICAL MAINTENANCE

This section describes the recommended maintenance of the optical components.

7.1.1 Blackbodies

There is no optical maintenance required for the blackbodies. The inner surface of the cavities is coated with a substance which can be damaged by probing which, therefore, should be avoided.

A vendor manual for the blackbodies is provided.

7.1.2 Telescopes

The telescopes should not require optical maintenance on a routine basis. Cleaning should be done only when the surface becomes very badly contaminated since the infrared performance is much better than the visual appearance usually indicates.

Alignment of the telescopes requires a large collimated source and considerable experience. Therefore, adjustments should not be made without these essentials.

It is recommended that, for cleaning or realignment, the telescopes be returned to the manufacturer, Perkin Elmer, Costa Mesa, California.

7.1.3 Reference Optics

The reference optics should need little maintenance aside from cleaning and readjustment of the spherical mirrors if the monochromator mount is relocated.

Cleaning of debris from the mirror surfaces can be done in many cases sufficiently by blowing gently on the surface with a clean gas jet. A more thorough cleaning might include the use of clean acetone to flood the surface and blowing the acetone off the edge before it evaporates. Collodion films may also be used to clean the surface by allowing the collodion solvent to evaporate and stripping the film.

Alignment of the reference optical system may be done by placing a lamp behind the entrance slit and aligning towards the blackbody or vice versa. Each element is aligned in turn to center the beam on the next element. The toroid should be rotated about the mount axis to change the symmetry of its image. The toroid or diagonal should be adjusted so that the intermediate focus passes through the center of the hole in the holder used for blocking the reference beam.

Refer to Section 4.2.6 for details of the reference chopper installation.

Refer to drawing 596-722-010 for details of the reference optical system.

7.1.4 Monochromator

Optical maintenance of the monochromator should not be required. Since the optical components are quite well protected, cleaning should not be necessary on a routine basis.

7.1.5 Detector Optics

The detector optics being enclosed should not require frequent cleaning. If required, the directions given under the Reference Optics section should be followed.

Alignment of the detector optical system should be done with a strong visible beam from the monochromator such as a mercury arc lamp or laser. The toroid should be adjusted to center the beam on the diagonal. The diagonal may be rotated in its mount to move the reflected image in the direction of the length of the detector. Alignment tools are provided which, in use, are placed on top of the detector housing. One is used to position the image at the first focal point of the Cassegrain assembly before its installation. The second is used to observe the image from the Cassegrain assembly at the detector location. Use of these devices will position the components closely enough so that all that is usually required is tweaking of the signal by positioning the dewar laterally and focussing the Cassegrain assembly (or what works about as well, over a limited range is focussing the toroid). In the latter case, however, use care not to distort the clips holding the toroid mirror in place.

Refer to drawing 596-722-011 for details of the detector optical system.

7.1.6 Detector

The principle maintenance task relating to the detector is its installation on the cold head of the detector cooler. Orientation of the detector, the heater, and sensor for the temperature controller and the hydrogen bulb for the vapor pressure thermometer are all shown on drawing 596-722-016.

To remove the detector it is only necessary to remove the flange of the dewar which contains the window, remove the mounting bolts and disconnect the leads. The leads are attached by means of 0.004 inch diameter Constantan wires, a supply of which is provided in the detector cooler kit.

Also included is a supply of indium for making gaskets for all components mounted on the cold head. These should always be used to assure a good heat transfer between the contact surfaces.

Although the detector is open within the dewar it should not be subjected to contamination by opening the dewar while the detector is still cold; about

3 hours is required for warmup. Should contamination occur, consult with the manufacturer, Santa Barbara Research Center, Goleta, Calif.

7.1.7 Synch System

The synch system should not need optical maintenance.

The source synch details are shown on drawing 596-722-017 and reference synch details are shown on drawing 596-722-010.

7.1.8 Alignment Device

The most probable maintenance task regarding the alignment devices is to check or reset their settings. This was done initially as follows.

In the laboratory line up the source and receiver assemblies carefully observing the images at the entrance slit and on the grating of the monochromator. Place a source behind the entrance slit and observe it with the boresight microscope at the source. Rig a temporary lamp and lens on the eyepiece end of the boresight microscope.for the monochromator so that the image of the lamp coincides with the crosshairs. Observe this by means of another microscope looking in the objective end. A small zirconium arc Point-o-lite was used but any small lamp will do. Then place the monochromator boresight microscope into place and adjust its diagonal so that the image falls in the same position in the field of the boresight microscope at the source as that of the image of the entrance slit. These images need not be centered; merely coincident. Repeat the procedure at the opposite end using a small pinhole at the source as the target. Place the lamp on the eyepiece end of the source boresight microscope and observe it with the boresight microscope at the monochromator. Adjust the diagonal of the source microscope until the target and lamp image coincides.

The wide field diagonal settings are not nearly so critical and may be set using any convenient object either in the laboratory or the field using the boresight microscopes as a guide.

7.2 MECHANICAL MAINTENANCE

This section describes the recommended mechanical maintenance.

7.2.1 Stands

The stand maintenance consists mainly of lubrication of the wheels and the screws on the front pads which should be required infrequently. The screws have been lubricated with a dry graphite lubricant; oils or greases should be avoided since they can hold abrasive material.

See drawing 596-722-006 for details of the front foot pads.

7.2.2 Auxiliary Stands

No mechanical maintenance is required.

7.2.3 Electronic Consoles

No mechanical maintenance is required.

7.2.4 Telescopes

The only probable mechanical maintenance is the straightening or replacement of taper pins used to align the telescope to the stand because of not removing the telescope in a straight line. See Section 4.2.5 for details of correcting this situation.

Although there are screws by means of which the telescope shell can be removed from the primary mirror cell these are not intended for normal disassembly since to do so would undoubtedly change the telescope adjustment.

7.2.5 Reference Optical System

No mechanical maintenance is required other than possible bearing replacement in the chopper or motor as indicated by roughness and noise. Refer to drawing 596-722-010 for chopper details and Section 4.2.6 regarding chopper assembly. For the chopper ultra precise bearings should be used as specified on the drawing. Use care not to damage the chopper blade or shaft during removal and reassembly.

7.2.6 Monochromator

No mechanical maintenance is required except for a few drops of oil infrequently in the wavenumber drive motor (the oil hole is on the bottom).

A vendor manual for the monochromator is provided.

7.2.7 Detector Optical System

No mechanical maintenance is necessary.

7.2.8 Detector Cooler

Maintenance of the detector cooler should be required only after extended periods and is covered in the vendor manual provided.

7.2.9 Synch Systems

No maintenance is required.

7.3 ELECTRICAL MAINTENANCE

This section describes the recommended electrical maintenance.

7.3.1 Signal Sources

The Hg:Ge detector and synch detectors have been covered in Sections 7.1 and 7.2 and should require no electrical maintenance.

7.3.2 Signal Amplifiers

The preamplifier, the selective amplifier and the lock-in amplifier are covered in vendor manuals provided.

The compensation amplifiers are described in detail in Section 4.3.3 and on drawing 596-722-027.

7.3.3 Data Acquisition System

The components within the logic box are of two types: standard boards for which a vendor manual is provided and Convair-built boards which are described in Section 4.3.5.

The control panel should require no electrical maintenance other than possible normal part replacement (such as switches).

The bidirectional counter is covered in a vendor manual which is provided.

The digital voltmeters are covered in a vendor manual which is provided.

7.3.4 Data Recording System

The electrical maintenance for the analog recorder, the digital printer, the digital tape recorder and the data coupler is covered in vendor manuals which are provided.

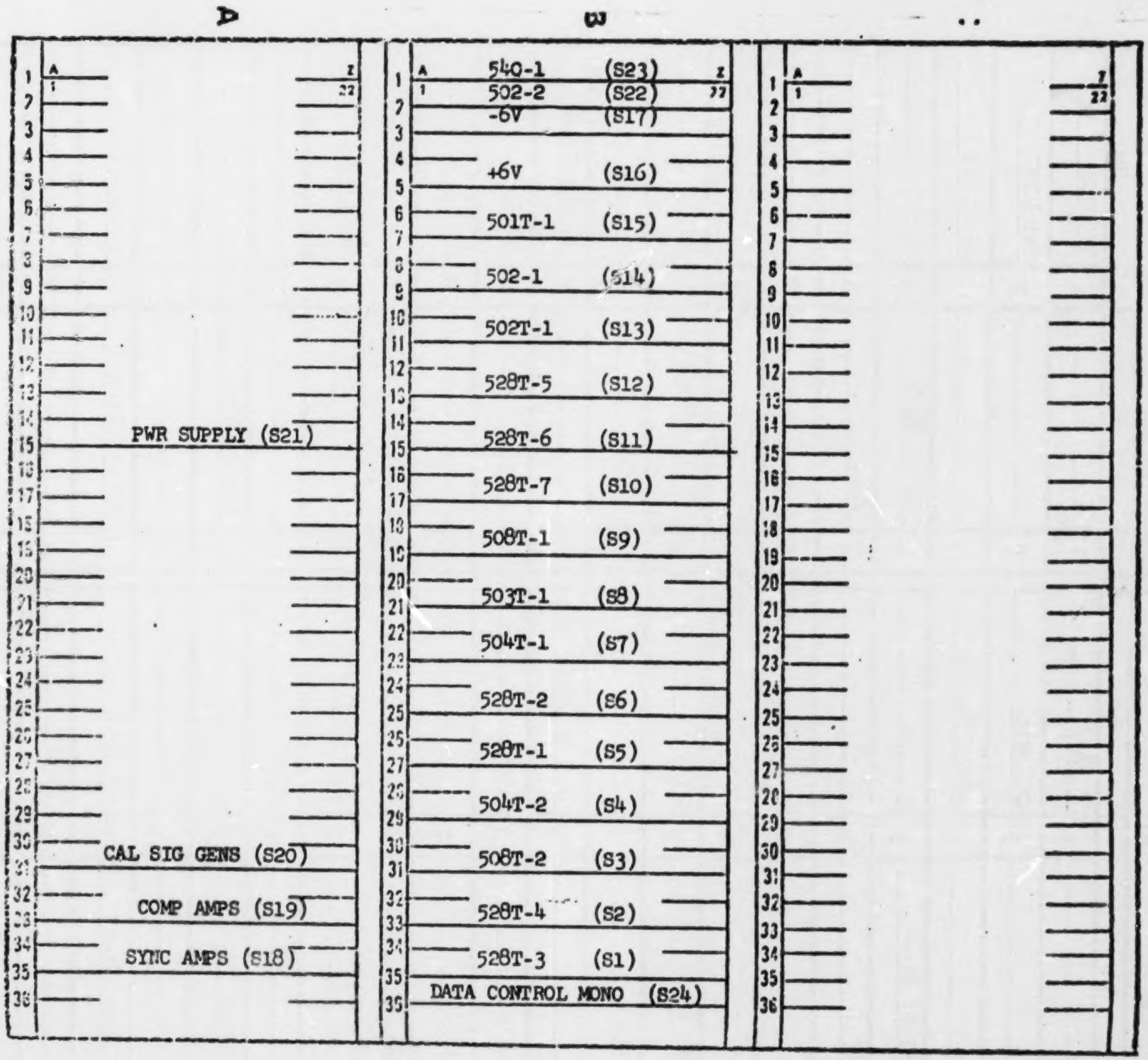
7.3.5 Power Sources

The ± 15 volt power source and the NIM BIN source are covered in vendor manuals provided. The reference chopper and the ± 6 volt power supplies are covered in Section 4.3.8.

7.3.6 Fuse List

The following list of fuses used in the various components is given here for convenient reference.

Component	Fuse
Digital Voltmeter 5403-015	½ Amp Slo Blo
Digital Voltmeter 5403-010	½ Amp Slo Blo
Bidirectional Counter	¾ Amp Slo Blo
Data Coupler	½ Amp Slo Blo
Digitil Printer	3 Amp Slo Blo
Digital Tape Recorder	2 Amp Slo Blo
NIM BIN	3 Amp Slo Blo (2 required)
Reference Chopper Supply	3 Amp Slo Blo
Analog Recorder	1 Amp Slo Blo
Monochromator Drive	1 Amp Slo Blo
Blackbody Controller	1½ Amp Slo Blo and 15 Amp Slo Blo
Detector Cooler Temp Control	¾ Amp Slo Blo
Blackbody Cooler	5 Amp Slo Blo
Thermocouple Gage	¼ Amp 3 AG
Source Chopper Drive	1 Amp Slo Blo



CARD LAYOUT
C3, C5 AND C2 CHASSIS

PAGE OF

CONNECTOR NO. S1

	To		To
1	S3-10	A	5V BUSS
2		B	GND BUSS
3		C	S5-C; S22-15
4	S1-8; S2-4	D	
5	S3-1	E	
6		F	
7		H	
8	S1-12; S1-8	J	S3-3
9	S3-2	K	
10		L	S1-16; S1-R
11		M	S3-4
12	S1-12; S1-16	N	
13	S1-18; S3-K	P	
14		R	S1-L; S1-V
15		S	S3-M
16	S1-12; S1-L	T	
17		U	
18	S4-M; S1-13	V	S1-R; S1-Z
19		W	S2-C
20		X	
21		Y	
22		Z	S1-R

CONNECTOR NO. S2

	To		To
1	S3-6	A	5V BUSS
2		B	GND BUSS
3		C	S1-W, S3-Y
4	S1-4; S2-8	D	
5	S3-8	E	
6		F	
7		H	
8	S2-4; S2-12	J	S4-7
9	S3-15	K	
10		L	S2-16; S2-R
11		M	S4-C
12	S2-8; S2-16	N	
13	S2-18	P	
14		R	S2-L; S2-V
15		S	
16	S2-12; S2-L	T	
17		U	
18	S2-13; S3-7	V	S2-R; S2-Z
19		W	
20		X	
21		Y	
22		Z	S2-V; S15-P

ROSE

Wire
List

PAGE OF

CONNECTOR NO.	S3		
	To		To
1	S3-11; S3-J	A	5V BUSS
2	S3-12; S1-9	B	GND BUSS
3	S1-J; S3-L	C	
4	S1-M; S3-W	D	
5	S3-N	E	S3-15; S4-12
6	S2-1; S3-13	F	S3-13; S3-S
7	S2-16; S4-L	H	S3-10; S3-T
8	S2-5; S3-14	J	S3-1; S3-U
9	J101-19	K	S1-13
10	S1-1; S3-H	L	S3-3; S4-4
11		M	S1-S; S3-X
12	S3-2; S3-V	N	S3-5; S3-Y
13	S3-6; S3-F	P	J101-22
14	S3-8; S3-R	R	S3-14; S4-D
15	S2-9; S3-E	S	S3-F; S4-6
16		T	S3-H, S4-9
17		U	S3-J
18	J101-21	V	S3-12; S4-10
19		W	S3-4; S4-F
20		X	S4-J
21		Y	S3-N; S4-S
22		Z	J101-25

CONNECTOR NO.	S4		
	To		To
1		A	5V BUSS
2		B	GND BUSS
3	J101-18	C	S2-M
4	S3-L	D	S3-R
5	S4-K	E	S4-11
6	S3-S; S4-11	F	S3-W; S4-P
7	S2-J	H	J101-17
8	J101-23	J	S3-X; S4-R
9	S3-T	K	S4-3
10	S3-V; S4-T	L	S3-7
11	S4-6; S4-E	M	S1-18
12	S3-E; S4-S	N	J101-20
13		P	S4-F
14		R	S4-J
15		S	S3-Y, S4-12
16		T	S4-10
17		U	J101-24
18		V	
19		W	
20		X	
21		Y	
22		Z	

ROSE

Wire
List

PAGE OF

CONNECTOR NO. S5

	To		To
1	S7-4	A	5V BUSS
2		B	GND BUSS
3		C	S1-C: S23-4
4	S5-8	D	
5	S7-10	E	
6		F	
7		H	
8	S5-4: S5-12	J	S7-16
9	S7-T	K	
10		L	S5-16; S5-R
11		M	S7-17
12	S5-12: S5-16	N	
13	S5-18	P	
14		R	S5-L; S5-V
15		S	S7-5
16	S5-12; S5-L	T	
17		U	
18	S5-13; S7-11	V	S5-R; S5-Z
19		W	S6-C
20		X	
21		Y	
22		Z	S5-V; S6-4

CONNECTOR NO. S6

	To		To
1	S7-7	A	5V BUSS
2		B	GND BUSS
3		C	S5-W; S7-6
4	S5-Z; S6-8	D	
5	S7-C	E	
6		F	
7		H	
8	S6-4; S15-K	J	
9		K	
10		L	
11		M	
12		N	
13		P	
14		R	
15		S	
16		T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	

ROSE

Wire
List

PAGE OF

CONNECTOR NO. S7

	To		To
1		A	5V BUSS
2		B	GND BUSS
3	J101-2	C	S6-5
4	S5-1; S7-9	D	S7-7; S9-5
5	S5-S; S7-12	E	S7-6
6	S6-C; S7-E	F	S7-10; S7-M
7	S6-1; S7-D	H	J101-1
8	J101-8	J	S7-12; S8-5
9	S7-4; S7-14	K	S7-16; S7-R S8-J
10	S5-5; S7-F	L	S7-15; S7-S
11	S5-18; S7-15 S9-8	M	S7-F; S8-K
12	S7-5; S7-J	N	J101-6
13	J101-12	P	S7-17; S8-4
14	S7-9; S8-8	R	S7-K
15	S7-11; S7-L	S	S7-L
16	S5-J; S7-K	T	S5-9; S8-2
17	S5-M; S7-P	U	J101-11
18		V	
19		W	
20		X	
21		Y	
22		Z	

CONNECTOR NO. S8

	To		To
1	S8-J	A	5V BUSS
2	S7-T; S8-9	B	GND BUSS
3	J101-5	C	
4	S7-P; S8-E	D	S8-10; S8-H
5	S7-J; S8-10	E	S8-4; S9-6
6		F	J101-4
7	J101-9	H	S8-D; S8-N
8	S8-1; S8-P	J	S7-K; S8-1
9	S8-2	K	S7-M; S9-7
10	S8-5; S8-D	L	J101-7
11		M	
12		N	S8-H
13		P	S8-8; S9-1
14		R	J101-10
15		S	S12-9
16		T	S12-5
17		U	S12-1
18		V	J102-2
19		W	
20		X	
21		Y	
22		Z	

ROSE

Wire
List

PAGE OF

CONNECTOR NO. S9

	To		To
1	S8-P	A	5V BUSS
2		B	GND BUSS
3		C	
4		D	
5	S7-D	E	
6	S8-E	F	
7	S8-K	H	
8	S7-11	J	
9	J101-3	K	
10		L	
11		M	
12		N	
13		P	
14		R	
15		S	
16		T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	

CONNECTOR NO. S10

	To		To
1	S13-11	A	5V BUSS
2		B	GND BUSS
3		C	S13-20 S22-J
4	S10-8	D	
5	S13-13	E	
6		F	
7		H	
8	S10-4; S10-12	J	S13-R
9	S13-12	K	
10		L	S10-16; S10-R
11		M	
12	S10-8, S10-16	N	
13	S10-18	P	
14		R	S10-L; S10-V
15		S	
16	S10-12; S10-L	T	
17		U	
18	S13-14	V	S10-R; S10-Z
19		W	
20		X	
21		Y	S10-V; S15-E
22		Z	

ROSE

Wire
List

PAGE OF

CONNECTOR NO. S11

	To		To
1	S13-5;	A	5V BUSS
2		B	GND BUSS
3		C	S5-C; S12-C
4	S11-8	D	
5	S13-6	E	
6		F	
7		H	
8	S11-4; S11-12	J	S13-4
9		K	
10		L	S11-16; S11-R
11		M	
12	S11-8; S11-16	N	
13	S11-18	P	
14		R	S11-L; S11-V
15		S	
16	S11-12; S11-L	T	
17		U	
18	S11-13	V	S11-R; S11-Z
19		W	
20		X	
21		Y	
22		Z	S11-V; S15-9

CONNECTOR NO. S12

	To		To
1	S8-U	A	5V BUSS
2		B	GND BUSS
3		C	S11-C
4	S12-8	D	
5	S8-T	E	
6		F	
7		H	
8	S12-4; S12-12	J	
9	S8-S	K	
10		L	
11		M	
12	S12-8; S12-16	N	
13		P	
14		R	
15		S	
16	S12-12; S15-5	T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	

ROSE

Wire
List

PAGE OF

CONNECTOR NO. S13

	To		To
1	J102-6	A	5V BUSS
2		B	GND BUSS
3		C	
4	S11-J; S13-7	D	
5	S11-1	E	
6	S11-5	F	
7	S13-A	H	
8	J02-5	J	J102-1
9		K	
10	J102-20	L	J102-19
11	S10-1; S13-M	M	S13-11; S13-Y
12	S10-9; S13-P	N	S13-13
13	S10-5; S13-N	P	S13-12
14	S10-13	R	S10-J
15	J102-21	S	J102-22
16		T	
17		U	
18		V	
19		W	
20	S10-C	X	
21		Y	S13-M
22	J102-17	Z	J102-18

CONNECTOR NO. S14

	To		To
1		A	5V BUSS
2		B	GND BUSS
3	S14-C	C	S14-3; S14-P
4		D	S14-8
5	S14-J	E	
6	S15-J J101-14	F	S15-N J101-27
7		H	
8	S14-D	J	S14-5
9		K	
10	S14-L J102-9	L	S14-10
11	S14-S	M	
12	S14-15	N	
13	S15-4 J102-3	P	S14-C; S14-X
14		R	
15	S14-M	S	S14-11
16		T	
17	S14-U J102-10	U	S14-17
18	S14-Z	V	S14-22
19		W	
20	S15-8 J102-7	X	S14-P
21		Y	
22	S14-V	Z	S14-18

ROSE

Wire
List

PAGE OF

CONNECTOR NO. S15

	To		To
1		A	5V BUSS
2		B	GND BUSS
3	S15-6	C	S15-F
4	S14-13	D	J102-23
5	S12-16	E	S10-Z
6	S15-3	F	S24-F; S15-C
7	S15-10	H	S15-L
8	S14-20	J	S14-6
9	S11-Z	K	S6-8
10	S15-7	L	S15-H
11		M	S15-R
12		N	S14-F
13		P	S2-Z
14		R	S15-M
15		S	
16		T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	

CONNECTOR NO. S16

	To		To
1		A	J103-2 S17-E
2		B	GND BUSS
3		C	XFORM OUTPUT HIGH
4		D	XFORM OUTPUT LOW
5		E	
6		F	
7		H	2N4240C
8		J	
9		K	
10		L	
11		M	
12		N	
13		P	2N4240E
14		R	
15		S	
16		T	
17		U	
18		V	2N4240B
19		W	
20		X	
21		Y	
22		Z	

ROSE

Wire
List

PAGE OF

CONNECTOR NO. S17

	To		To
1		A	J103-3
2		B	GND BUSS
3		C	XFORM OUTPUT HIGH
4		D	XFORM OUTPUT LOW
5		E	
6		F	
7		H	
8		J	
9		K	
10		L	
11		M	
12		N	
13		P	
14		R	
15		S	
16		T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	

CONNECTOR NO. S18

	To		To
1		A	-15V BUSS
2		B	GND BUSS
3		C	+15V BUSS
4		D	
5		E	J103-4
6		F	J103-5
7		H	
8		J	BNC 98 S20-Z
9		K	
10		L	J103-6
11		M	
12		N	
13		P	
14		R	
15		S	
16		T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	BNC 97 S20-C

ROSE

Wire
List

PAGE OF

CONNECTOR NO. S19

	To		To
1		A	-15V BUSS
2		B	GND BUSS
3		C	
4		D	
5		E	BNC 96
6		F	BNC 95
7		H	
8		J	
9		K	J102-13
10		L	
11		M	+15V BUSS
12		N	
13		P	J102-14
14		R	
15		S	
16		T	
17		U	
18		V	BNC 94
19		W	
20		X	
21		Y	
22		Z	J102-28

CONNECTOR NO. S20

	To		To
1		A	
2		B	GND BUSS
3		C	S18-Z
4		D	J102-26
5		E	-15V BUSS
6		F	
7		H	+15V BUSS
8		J	J102-27
9		K	
10		L	
11		M	
12		N	
13		P	BNC 97
14		R	
15		S	
16		T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	S18-J

ROSE

Wire
List

PAGE OF

CONNECTOR NO. S21

	To		To
1	115V 60 Hz GND	A	
2		B	
3		C	
4	115V 60 Hz	D	
5		E	
6		F	
7	115V 60 Hz Low	H	
8		J	
9		K	
10	GND BUSS	L	
11	GND BUSS	M	
12		N	
13		P	
14		R	
15		S	
16	-15V BUSS	T	
17		U	
18	+15V BUSS	V	
19		W	
20		X	
21	+5V BUSS	Y	
22	+5V BUSS	Z	

CONNECTOR NO. S22

	To		To
1		A	5V BUSS
2		B	GND BUSS
3	S22-F	C	S22-5
4	S23-19	D	J102-11
5	S22-6; S22-C	E	
6	S22-5	F	S22-3 COUNTER OUTPUT BNC(X)
7	S23-12	H	
8	COUNTER OUTPUT BNC(Y)	J	S10-C
9		K	
10		L	
11		M	
12		N	
13	J103-10	P	J103-1 S23-13
14		R	
15	S1-C; S22-5 S23-7	S	S22-15
16		T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	

ROSE

Wire List

PAGE OF

CONNECTOR NO.	S23		
	To		To
1		A	5V BUSS
2		B	GND BUSS
3			
4	S5-C		
5			
6			
7	S22-15		
8			
9			
10			
11			
12	S22-7		
13	S22-P		
14			
15	S23-B		
16			
17			
18			
19	S22-4		
20			
21			
22			

CONNECTOR NO.	S24		
	To		To
		A	5V BUSS
		B	GND BUSS
		C	
		D	
		E	
		F	S15-F
		H	J102-25

ROCE

Wire List

PAGE OF

CONNECTOR NO.	S25		
	To		To
1		23	
2		24	
3		25	
4		26	
5		27	
6		28	
7		29	P117-C
8		30	
9		31	
10	REC IN SW2-3 GND, P117-A	32	CONTROL PANEL PNC #81
11		33	
12		34	CONTROL PANEL PNC #80
13		35	P117-B
14		36	
15		37	
16		38	
17		39	
18		40	
19		41	
20		42	
21		43	
22		44	

CONNECTOR NO.	S25		
	To		To
45			
46			
47	REC IN SW1-3		

ROSE

Wire List

PAGE OF

CONNECTOR NO. J1

	To		To
A	B.B. CONTROL GND		
B	B.B. CONTROL HEATER		
C	B.B. CONTROL HEATER		
D	B.B. CONTROL FAN		
E	B.B. CONTROL SENSOR(-)		
F	B.B. CONTROL SENSOR (+)		
G	B.B. CONTROL FAN		

CONNECTOR NO.

	To		To
A	P112-A		
B	P112-B		
C	P112-C		
D	P112-D		
E	P112-E		
F	P112-F		
G	P112-G		

ROSE

Wire
List

PAGE OF

CONNECTOR NO. J2

	To		To
A	BLACKBODY GND		
B	BLACKBODY HEATER		
C	BLACKBODY HEATER		
D	BLACKBODY FAN		
E	BLACKBODY SENSOR(-)		
F	BLACKBODY SENSOR(+)		
G	BLACKBODY FAN		

CONNECTOR NO. P2

	To		To
A	J112-A		
B	J112-B		
C	J112-C		
D	J112-D		
E	J112-E		
F	J112-F		
G	J112-G		

ROSE

Wire
List

PAGE OF

CONNECTOR NO. J101

	To		To
1	S7-H	23	S4-8
2	S7-3	24	S4-U
3	S9-9	25	S3-Z
4	S8-F	26	GND BUSS
5	S8-3	27	S14-F
6	S7-N	28	
7	S8-L	29	
8	S7-8	30	
9	S8-7	31	
10	S8-R	32	
11	S7-U		
12	S7-13		
13	GND BUSS		
14	S14-6		
15			
16			
17	S4-H		
18	S4-3		
19	S3-9		
20	S4-H		
21	S3-18		
22	S3-P		

CONNECTOR NO. J102

	To		To
1	S13-J	23	S15-D
2	S8-V	24	GND BUSS
3	S14-13	25	S24-F
4	GND BUSS	26	S20-D
5	S13-8	27	S20-J
6	S13-3	28	S19-Z
7	S14-20	29	J107-A
8	GND BUSS	30	J107-B
9	S14-10	31	J103-8
10	S14-17	32	J103-9
11	S23-D		
12	GND BUSS		
13	S19-K		
14	S19-P		
15			
16			
17	S13-22		
18	S13-Z		
19	S13-L		
20	S13-10		
21	S13-15		
22	S13-8		

ROSE

Wire
List

PAGE OF

CONNECTOR NO. P101

	To		To
1	TENS SELECTOR SW. Pos. 10	23	ONES SELECTOR SW. Pos. 7
2	TENS SELECTOR SW. Pos. 20	24	ONES SELECTOR SW. Pos. 8
3	TENS SELECTOR SW. Pos. 30	25	ONES SELECTOR SW. Pos. 9
4	TENS SELECTOR SW. Pos. 50	26	
5	TENS SELECTOR SW. Pos. 90	27	ONES SELECTOR SW Wiper
6	TENS SELECTOR SW. Pos. 100	28	
7	TENS SELECTOR SW. Pos. 110	29	
8	TENS SELECTOR SW. Pos. 120	30	
9	TENS SELECTOR SW. Pos. 130	31	
10	TENS SELECTOR SW. Pos. 170	32	
11	TENS SELECTOR SW. Pos. 150		
12	TENS SELECTOR SW. Pos. 160		
13	SHIELDS & PANEL GND		
14	TENS SELECTOR SW. Wiper		
15			
16			
17	ONES SELECTOR SW. Pos. 1		
18	ONES SELECTOR SW. Pos. 2		
19	ONES SELECTOR SW. Pos. 3		
20	ONES SELECTOR SW. Pos. 4		
21	ONES SELECTOR SW. Pos. 5		
22	ONES SELECTOR SW. Pos. 6		

CONNECTOR NO. P102

	To		To
1	COARSE SELECT 3-5.S (1125)	23	RESO. SELECTOR SW. Wiper
2	COARSE SELECT 3-5.S (1286)	24	
3	COARSE SELECT 3.5-S Wiper	25	DATA CONTROL BNC
4		26	STD. SIGNAL Pot. Hi Side
5	COARSE SELECT 7-13.5 (500)	27	STD. SIGNAL Pot. Wiper
6	COARSE SELECT 7-13.5 (529)	28	SOURCE COMP AMP OUT BNC
7	COARSE SELECT 7-13.5 Wiper	29	REF. OSC. SW. On
8		30	REF. OSC. SW. Wiper
9	MODE SELECTOR SW. 3-5.5	31	REF. TEMP. SENSOR OUTPUT
10	MODE SELECTOR SW. 7-13.5	32	REF. TEMP. PROBE OUTPUT
11	MODE SELECTOR SW. Wiper		
12	SHIELDS & PANEL GND		
13	SIG % ADJ HI SIDE		
14	SIG % ADJ WIPER		
15			
16			
17	RESO. SELECTOR SW. Pos. 1		
18	RESO. SELECTOR SW. Pos. 2		
19	RESO. SELECTOR SW. Pos. 3		
20	RESO. SELECTOR SW. Pos. 5		
21	RESO. SELECTOR SW. Pos. 1		
22	RESO. SELECTOR SW. Pos. 2		

ROSE

Wire
List

PAGE OF

CONNECTOR NO. J103

	To		To
1	S22-P	A	
2	S16-A	B	
3	S17-A	C	
4	S18-E	D	
5	S18-F	E	
6	S18-L	F	
7	GND BUSS	H	
8	J102-31	J	
9	J102-32	K	
10	S22-13	L	
11		M	
12		N	
13		P	
14		R	
15		S	
16	GND BUSS	T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	

CONNECTOR NO. P103

	To		To
1	P104-1	A	
2	P104-2	B	
3	P104-3	C	
4	P104-4	D	
5	P104-5	E	
6	P104-6	F	
7	P104-7	H	
8	P104-8	J	
9	P104-9	K	
10	P104-10	L	
11		M	
12		N	
13		P	
14		R	
15		S	
16	P104-16	T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	

ROSE

Wire List

PAGE OF

CONNECTOR NO. J104

	To		To
1	J106-1	A	
2	J106-4 J111-A	B	
3	J106-3	C	
4	J111-C	D	
5	J111-D	E	
6	P116-1	F	
7	GND J106-5 J111-B	H	
8	REF TEMP SENSOR OUTPUT	J	
9	REF TEMP PROBE OUTPUT	K	
10	J106-2	L	
11		M	
12		N	
13		P	
14		R	
15		S	
16	P116-2 REF TEMP GND	T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	

CONNECTOR NO. J105

	To		To
1	P108-1	A	
2	P108-2	B	
3	P108-3	C	
4	P108-4	D	
5	P108-5	E	
6	P108-6	F	
7	P108-7	H	
8	P108-8	J	
9	J110-A	K	
10	J110-B	L	
11		M	
12		N	
13		P	
14		R	
15		S	
16		T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	

ROSE

Wire List

PAGE OF

CONNECTOR NO. P104

	To		To
1	P103-1	A	
2	P103-2	B	
3	P103-3	C	
4	P103-4	D	
5	P103-5	E	
6	P103-6	F	
7	P103-7	H	
8	P103-8	J	
9	P103-9	K	
10	P103-10	L	
11		M	
12		N	
13		P	
14		R	
15		S	
16	P103-16	T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	

CONNECTOR NO. P105

	To		To
1	MONOCHROMATOR CONTROLLER TB3-1	A	
2	MONOCHROMATOR CONTROLLER TB3-2	B	
3	MONOCHROMATOR CONTROLLER TB3-3	C	
4	MONOCHROMATOR CONTROLLER TB3-4	D	
5	MONOCHROMATOR CONTROLLER TB3-5	E	
6	MONOCHROMATOR CONTROLLER TB3-6	F	
7	MONOCHROMATOR CONTROLLER TB3-7	H	
8	MONOCHROMATOR CONTROLLER TB3-8	J	
9	MONOCHROMATOR CONTROLLER TB2-6	K	
10	MONOCHROMATOR CONTROLLER TB2-7	L	
11		M	
12		N	
13		P	
14		R	
15		S	
16		T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	

ROSE

Wire
List

PAGE OF

CONNECTOR NO. P106

	To		To
1	P109-A	A	
2	P109-C	B	
3	P109-H	C	
4	P109-J	D	
5	P109-L	E	
6		F	
7		H	
8		J	
9		K	
10		L	
11		M	
12		N	
13		P	
14		R	
15		S	
16		T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	

CONNECTOR NO. J106

	To		To
1	J104-1	A	
2	J104-10	B	
3	J104-3	C	
4	J104-2	D	
5	J104-7	E	
6		F	
7		H	
8		J	
9		K	
10		L	
11		M	
12		N	
13		P	
14		R	
15		S	
16		T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	

ROSE

Wire
List

PAGE OF

CONNECTOR NO. J107

	To		To
1		A	J102-29
2		B	J102-30
3		C	
4		D	
5		E	
6		F	
7		H	
8		J	
9		K	
10		L	
11		M	
12		N	
13		P	
14		R	
15		S	
16		T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	

CONNECTOR NO. P107

	To		To
1		A	REF. OSC. AC PWR IN
2		B	REF. OSC. AC HI
3		C	
4		D	
5		E	
6		F	
7		H	
8		J	
9		K	
10		L	
11		M	
12		N	
13		P	
14		R	
15		S	
16		T	
17		U	
18		V	
19		W	
20		X	
21		Y	
22		Z	

ROSE

Wire
List

PAGE OF

CONNECTOR NO.	J108		
	To		To
1	MONOCHROMATOR AC		
2	MONOCHROMATOR LIMIT S.		
3	MONOCHROMATOR λ MOTOR		
4	MONOCHROMATOR ACC		
5	MONOCHROMATOR SPEED 1		
6	MONOCHROMATOR SPEED 2		
7	MONOCHROMATOR SPEED 4		
8	MONOCHROMATOR AUTO SPEED		

CONNECTOR NO.	P108		
	To		To
1	J105-1		
2	J105-2		
3	J105-3		
4	J105-4		
5	J105-5		
6	J105-6		
7	J105-7		
8	J105-8		
9			
10			

ROSE

Wire
List

PAGE OF

CONNECTOR NO. J109

	To		To
A	ENCODER CW PULSES		
B			
C	ENCODER CCW PULSES		
D			
E			
F			
G			
H	ENCODER -6V		
J	ENCODER +6V		
K	ENCODER LAMPS		
L	ENCODER GND		

CONNECTOR NO. P109

	To		To
A	P106-1		
B			
C	P106-2		
D			
E			
F			
G			
H	P106-3		
J	P106-4		
K	P109-J		
L	P106-5		

ROSE

Wire
List

PAGE OF

CONNECTOR NO. P110

.	To		To
A	CHOPPER RED MOTOR		
B	CHOPPER BRN MOTOR WHT/BLU		
C	CHOPPER BLK MOTOR		

CONNECTOR NO. J110

	To		To
A	J105-9		
B	J105-10		
C	CAPACITOR		

ROSE

Wire
List

PAGE OF

CONNECTOR NO. P111

.	To		To
A	REF SYNC LAMP +V		
B	REF SYNC LAMP GND		
C	REF SYNC DET HP 4205-A		
D	REF SYNC DET HP 4205-C		

CONNECTOR NO. J111

	To		To
A	J104-2		
B	J104-7		
C	J104-4		
D	J104-5		

ROSE

Wire
List

PAGE OF

CONNECTOR NO.	J112		
	To		To
A	P2-A		
B	P2-B		
C	P2-C		
D	P2-D		
E	P2-E		
F	P2-F		
G	P2-G		

CONNECTOR NO.	P112		
	To		To
A	P1-A		
B	P1-B		
C	P1-C		
D	P1-D		
E	P1-E		
F	P1-F		
G	P1-G		

ROSE

Wire List

PAGE OF

CONNECTOR NO. J113

	To		To
A	P114-28 P116-4		
B	P114-29 P116-6		
C	P114-34		

CONNECTOR NO. [illegible]

	To		To
A	P115-5		
B	P115-7		
C	P115-6		

ROSE

Wire List

PAGE OF

CONNECTOR NO. J114

	To		To
28	PREAMP +24V		
29	PREAMP -24V		
34	PREAMP GND		

CONNECTOR NO. P114

	To		To
28	J113-A		
29	J113-B		
34	J113-C		

ROSE

Wire List

PAGE OF

CONNECTOR NO. J115

	To		To
1			
2			
3			
4			
5	NIM BIN +24V		
6	NIM BIN GND		
7	NIM BIN -24V		
8			

CONNECTOR NO. P115

	To		To
1			
2			
3			
4			
5	P113-A		
6	P113-C		
7	P113-B		
8			

ROSE

Wire List

PAGE OF

CONNECTOR NO. J116

	To		To
1	SYNC PREAMP SIG HI		
2	SYNC PREAMP SIG LOW		
3			
4	+24 VOLTS		
5			
6	-24 VOLTS		
7			

CONNECTOR NO. P116

	To		To
1	J104-6		
2	J104-16		
3			
4	J113-A		
5			
6	J113-B		
7			

ROSE

Wire
List

PAGE OF

CONNECTOR NO. J117

	To		To
A	GND		
B	+24V		
C	-24V		
D			
E			
F			
H			

CONNECTOR NO. P117

	To		To
A	S25-10		
B	S25-35		
C	S25-29		
D			
E			
F			
H			

ROSE

Wire
List

PAGE OF

CONNECTOR NO. J118

	To		To
A	Counter Gnd		
B	Counter A7-26 *		
C	Counter A6-26		
D	Counter A5-26		

CONNECTOR NO. P118

	To		To
A	Marker Selector Gnd		
B	Marker Selector a1		
C	Marker Selector a4		
D	Marker Selector a9		

* Least Significant Decade

ROSE

Wire
List

PAGE OF

CONNECTOR NO. J119

	To		To
1			
2			
3	REC IN SIG- WIPER		
4			
5			
6	REC IN SIG- WIPER		
7			
8			

CONNECTOR NO. P119

	To		To
1			
2			
3	RECORDER + SIG IN		
4			
5			
6	RECORDER - SIG IN		
7			
8			

ROSE

Wire
List

PAGE OF

CONNECTOR NO. J120

	To		To
A	Lock in Gnd		
B	Lock in + 24V		

CONNECTOR NO. P120

	To		To
A	Marker Selector Gnd		
B	Marker Selector 24V Input		

ROSE

Wire
List

PAGE OF

CONTROL PANEL WIRING

	From	To		From	To
1			1		
2			2		
3	LOGIC OUTPUT BNC	LOGIC OUTPUT BANANAS	3		
4	LOGIC OUTPUT BNC	BAND SELECTOR WIPER	4		
5	RESO. SELECTOR SW OFF	PANEL GND	5		
6	DATA CONTROL BNC	DATA CONTROL BANANAS	6		
7	DATA CONTROL BNC	RESO. SELECTOR SW WIPER	7		
8	SOURCE LOCK-IN AMP INPUT BNC	SOURCE LOCK-IN AMP BANANAS	8		
9	SOURCE LOCK-IN AMP INPUT BNC	BNC NO. 82	9		
10	SOURCE COMP. AMP OUT BNC	SOURCE COMP. AMP OUT BANANAS	10		
11			11		
12	SIG. T ADJUST LOW SIDE	PANEL GND	12		
13	STD SIGNAL T ADJUST LOW SIDE	PANEL GND	13		
14	REF LOCK-IN AMP INPUT BNC	REF LOCK-IN AMP BANANAS	14		
15	REF LOCK-IN AMP INPUT BNC	BNC NO. 83	15		
16	REF COMP AMP OUTPUT BNC	REF COMP AMP OUTPUT BANANAS	16		
17	REF COMP AMP OUTPUT BNC	BNC NO. 81	17		
18	REF SYNC DET OUTPUT BNC	BNC NO. 85	18		
19	SOURCE SYNC DET OUTPUT BNC	BNC NO. 84	19		
20	INPUT STATE SW OPERATE	BNC NO. 87	20		
21	INPUT STATE SW. STD. SIGNAL	BNC NO. 86	21		
22	INPUT STATE SW WIPER	BNC NO. 88	22		

ROSE

Wire List

PAGE OF

COAXIAL CABLES

	From	To		From	To
1	BNC NO. 81	BNC NO. 94	1	BNC NO. 80	S25-34 I/I_o MODULE
2	BNC NO. 82	BNC NO. 95	2	BNC NO. 81	S25-32 I/I_o MODULE
3	BNC NO. 83	BNC NO. 96	3	BNC NO. 81	REC IN SW2-1
4	BNC NO. 84	BNC NO. 97	4	BNC NO. 80	REC IN SW2-2
5	BNC NO. 85	BNC NO. 98	5		
6	BNC NO. 86	BNC NO. 99	6		
7	BNC NO. 87	PREAMP OUTPUT	7		
8	BNC NO. 88	SOURCE SEL AMP INPUT (REAR)	8		
9	LOGIC CHASSIS COUNTER OUTPUT(X	COUNTER INPUT(X)	9		
10	PANEL DATA CONTROL OUT	DVM 5403-15 EXTERNAL READ	10		
11	PANEL SOURCE LOCK-IN AMP IN	SOURCE LOCK-IN AMP OUTPUT	11		
12	PANEL SOURCE COMP AMP OUT	DVM 5403-10 INPUT	12		
13	PANEL REFERENCE LOCK-IN AMP IN	REF LOCK-IN AMP OUTPUT	13		
14	PANEL REFERENCE COMP AMP OUT	DVM RATIO INPUT	14		
15	PANEL REFERENCE SYNC REF OUT	REF LOCK-IN REF INPUT	15		
16	PANEL SOURCE SYNC REF OUT	SOURCE LOCK-IN REF INPUT	16		
17	DVM 5403-15 EXTERNAL READ	DATA COUPLER J7	17		
18	DVM 5403-10 INPUT	DVM 5403-15 INPUT	18		
19	SOURCE SEL AMP INPUT	REF SEL AMP INPUT	19		
20	SOURCE SEL AMP OUTPUT	SOURCE LOCK-IN AMP INPUT	20		
21	REF SEL AMP OUTPUT	REF LOCK-IN AMP INPUT	21		
22	LOGIC CHASSIS COUNTER INPUT(Y)	COUNTER INPUT(Y)	22		

ROSE

Wire
List

PAGE OF

RECORDER INPUT SW1	
From	To
SW1-1	CONTROL PANEL BNC NO. 81 SHIEL
SW1-2	CONTROL PANEL BNC NO. 80 SHIEL
SW1-3	S25-47
SW1-WIPER	J119-6

RECORDER INPUT SW2	
From	To
SW2-1	CONTROL PANEL BNC NO. 81
SW2-2	CONTROL PANEL BNC NO. 80
SW2-3	S25-10
SW2-WIPER	J119-3

ROSE

Wire List

PAGE OF

DATA ACQUISITION SYSTEM CABLES

	From	To		From	To
1	DATA COUPLER J1	DVM 5403-15 J202 & J204	1		
2	DATA COUPLER J2	DVM 5403-10 J202 & J204	2		
3	DATA COUPLER J3	COUNTER J5 & J6	3		
4	DATA COUPLER J4	PRINTER A1J1	4		
5	DATA COUPLER J5	PRINTER A1J2	5		
6	DATA COUPLER J6	TAPE RECORDER J6	6		
7	DATA COUPLER J7	DVM 5403-15 EXTERNAL READ	7		
8	STRIP CHART J5-A	SOURCE LOCK-IN AMP OCTAL-3	8		
9	STRIP CHART J5-B	SOURCE LOCK-IN AMP OCTAL-5	9		
10	STRIP CHART J5-SHIELD	STRIP CHART J5-C	10		
11	STRIP CHART J13-A	MONOCHROMATOR CONTROLLER TB2-3	11		
12	STRIP CHART J13-B	STRIP CHART J13-E	12		
13	STRIP CHART J13-E	MONOCHROMATOR CONTROLLER TB2-5	13		
14	STRIP CHART J13-C	MONOCHROMATOR CONTROLLER TB2-2	14		
15			15		
16			16		
17			17		
18			18		
19			19		
20			20		
21			21		
22			22		

ROSE

Wire
List

PAGE OF

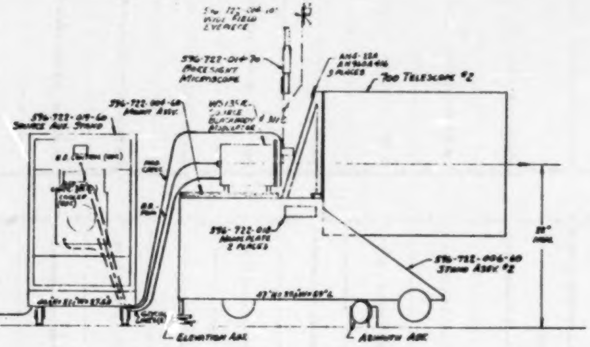
MONOCHROMATOR CONTROLLER

	From	To		From	To
1	TB1-1	AC HOT	1		
2	TB1-2	AC GND	2		
3	TB2-2	STRIP CHART CABLE SHIELD	3		
4	TB2-3	STRIP CHART J-13A	4		
5	TB2-5	STRIP CHART J13-B	5		
6	TB3-1	P105-1	6		
7	TB3-2	P105-2	7		
8	TB3-3	P105-3	8		
9	TB3-4	P105-4	9		
10	TB3-5	P105-5	10		
11	TB3-6	P105-6	11		
12	TB3-7	P105-7	12		
13	TB3-8	P105-8	13		
14	TB2-6	P105-9	14		
15	TB2-7	P105-10	15		
16			16		
17			17		
18			18		
19			19		
20			20		
21			21		
22			22		

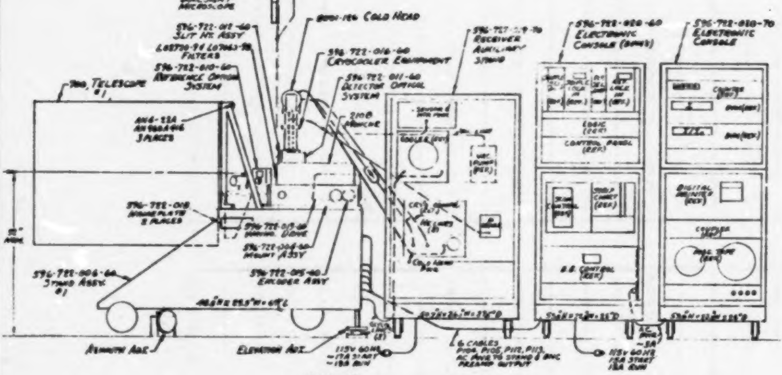
ROSE

Wire List

PAGE OF



-70 SOURCE ASSY.



-60 RECEIVER ASSY.

AS REQ'D					MISC. SCREWS FOR MOUNTING COMPONENTS.			
3	3				AN960A416	WASHER		
3	3				AN4-12A	BOLT		1/4-28 x 2 9/32 (1 5/16 [illegible])
1					311C	MODULATOR		ELECTRO OPTICAL INDUSTRIES SANTA BARBARA CALIF.
1					WS135R (AS-2 [illegible])	BLACKBODY		" " " " " "
1					700	TELESCOPE #2		PERKIN ELMER-COSTA MESA CALIF 24" DIA. 120" F.L. DALL KIRKHAM
1					596-722-017-60	SOURCE AUXILIARY STAND		
2					018	NAMEPLATE		
1					014-100	WIDE FIELD EYEPIECE		
1					014-70	BORESIGHT MICROSCOPE		
1					006-60	STAND ASSY #2		
1					596-722-004-60	BLACKBODY MOUNT ASSY		
	1				S/N 8001-126R	CRYOCOOLER COLD HEAD		CRYOGENIC TECHNOLOGY INC. WALTHAM MASS. (PART OF MODEL 80 SYSTEM)
	1				700	TELESCOPE #1		PERKIN ELMER COSTA MESA CALIF. 24" DIA. 120" F.L. DALL KIRKHAM
	1				L02720-9	3µ CUTOFF FILTER		OCLI, SANTA ROSA CALIF. (INSTALLED IN MONOCH. FILTER WHEEL)
	1				L07060-9F	7µ CUTOFF FILTER		" " " " " " " " "
	1				210B	MONOCHROMATOR		PERKIN ELMER NORWALK, CONN. (INCL. 106 AND 107 [illegible])
	1				596-722-030-70	ELECTRONIC CONSOLE		
	1				020-60	ELECTRONIC CONSOLE ([illegible])		
	1				019-70	RECEIVER AUXILIARY STAND		
	2				018	NAMEPLATE		
	1				017-60	SYNCH [illegible] ASSY		
					016-60	CRYOCOOLER EQUIPMENT		
					015-60	ENCODER ASSY		
					014-90	WIDE FIELD EYEPIECE		
	1				014-60	BORESIGHT MICROSCOPE		
	1				013-60	MAN. WHEEL DRIVE ASSY		
	1				012-60	SLIT HEIGHT ASSY		
	1				011-60	DETECTOR OPTICAL SYSTEM		
					010-60	REF. OPTICAL SYSTEM		
	1				006-60	STAND ASSY #1		
	1				596-722-004-90	MONOCHROMATOR MOUNT ASSY		
-70	-60	UNIT OF MEAS	ITEM OR FIND NO.	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION		(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT
REQ PER ASSY / INSTL							NOTE SYMBOL: E—END ITEM G—GENERAL NOTE L—LIMIT M—MATERIAL R—REFERENCE DESIGNATION S—STOCK NO. U—USAGE DATA	

PARTS LIST

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES √
RIVET BASIC CODE-MA5403
BB—MS20426AD
BJ—MS20470AD

SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS
SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS
ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
LA ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ±.1 .XX ±.03 .XXX ±.010
ANGULAR PER 0-70902

MATL
FINISH

CHECK
STRESS
GR ENGR
DESIGN M.L. SKENT 7/14/70
DRAWN
CONTRACT NO.

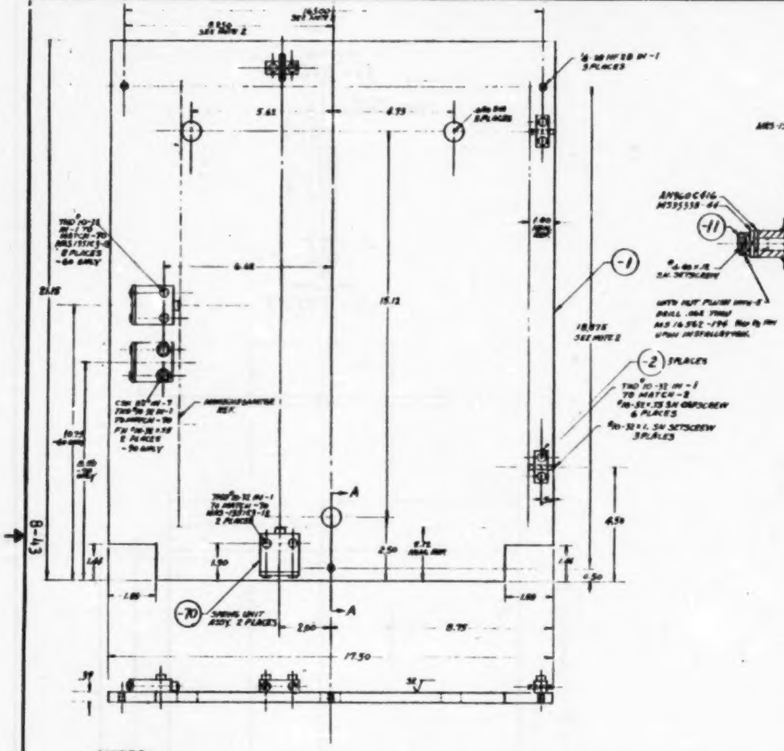
SECURITY CLASSIFICATION

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

GENERAL ASSY-REMOTE OPTICAL SENSING OF EMISSION SYSTEM

SIZE	CODE IDENT	DRAWING NO.
D	14170	596-722-003

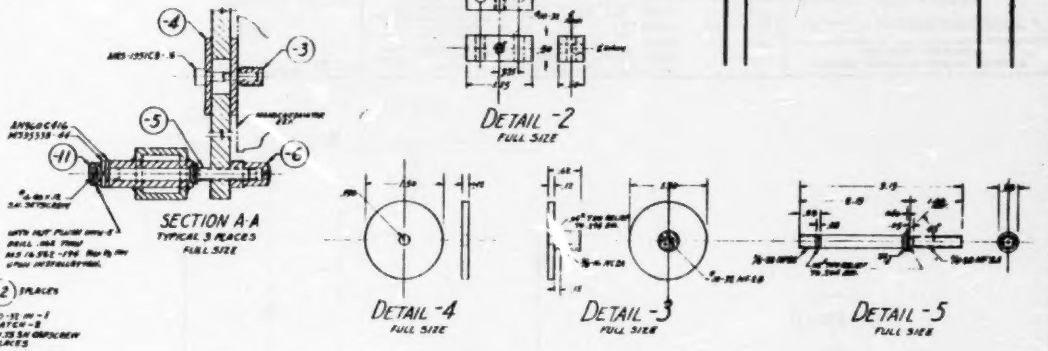
SCALE 1/10 RELEASED SHEET 1 OF 1
PACKAGE NO.



8.250 SEE NOTE 2
16.500 SEE NOTE 2
1/4-20 HF 28 IN -1 3 PLACES
5.62
4.75
3 PLACES
THD #10-32 IN -1 TO MATCH -70 NAS1351C3-12 8 PLACES -60 ONLY
6.48
15.12
1.00
-1
18.875 SEE NOTE 2
21.75
-2 3 PLACES
THD #10-32 IN -1 TO MATCH -2 #10-32 × .75 SH CAPSCREW 6 PLACES
#10-32 × 1. SH SETSCREW 3 PLACES
MONOCHROMATOR REF.
A
A
-70 SPRING UNIT ASSY. 2 PLACES
2.50
4.50
1.44
1.50
1.88
2.00
8.75
17.50
.38

NOTES:

1. Break all sharp corners.
2. To match 596-722-005-60. See M.S. Payne Dept 451 for match plate.
3. Black anodize parts listed by G in note symbol column.



-90	-80	-70	-60	UNIT OF MEAS	ITEM OR FIND NO.	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	NOTE	(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT)	
2								#10-32 × .75 LONG F.H. SCREW		CRES	
3			3				NAS1351C3-16	#10-32 × 1 LONG S.H. CAPSCREW		"	
8			10				NAS1351C3-12	10-32 × .75 LG. S.H. CAPSCREW		"	
3			3					#4-40 × .12 LG S.H. SETSCREW		"	
3			3					#10-32 × 1 LG S.H. SETSCREW		"	
		2						#6-32 × .38 PAN HD SCREW		"	
3			3				MS 35338-44	1/4 LOCKWASHER (Cd Pl)			
3			3				AN960C416	1/4 WASHER		CRES	
3			3				MS16562-194	1/16 × 1/2 TUBULAR PIN		"	
2			2				-70	SPRING UNIT ASSY			
	4						-13	SPACER	G	.50 DIA × 2 2024-T851 ALUM ROD	QQ-A-225/6
	1						-12	PLATE	G	.38 × 18 × 22 2024-T351 ALUM PLATE	QQ-A-250/4
3			3				-11	NUT		MAKE FROM AN315-4 (1/4-28 NUT)	
		1					-10	SPRING		.047 × 36 302 CRES SPRING TEMPER WIRE	QQ-W-423
		1					-9	COVER	G	12 × .6 × 1.6 2024-T3 ALUM SHEET	QQ-A-250/5
		1					-8	PLUNGER	G	.38 DIA × 2 2024-T4 ALUM ROD	QQ-A-225/6
		1					-7	HOUSING	G	.5 × 2 × 2 2024-T351 ALUM PLATE	QQ-A-250/4
3			3				-6	CAPNUT		.05 HEX × 1 321 ST. STL. BAR COND A	QQ-S-763 COMP 321
3			3				-5	STUD		.38 O.D. × 4 321 ST. STL. BAR COND A	" " " "
3			3				-4	WASHER	G	.125 × 2 × 2 2024-T3 ALUM SHEET	QQ-A-250/4
3			3				-3	ADAPTER	G	1.5 DIA × 1 2024-T851 ALUM ROD	QQ-A-225/6
3			3				-2	BLOCK	G	.5 × .5 × 1.5 " " " PLT	" "
1			1				-1	PLATE	G	.38 × 22 × 18 2024-T351 ALUM PLATE	QQ-A-250/4

REQ PER ASSY / INSTL

NOTE SYMBOL: E—END ITEM G—GENERAL NOTE L—LIMIT M—MATERIAL R—REFERENCE DESIGNATION S—STOCK NO. U—USAGE DATA

PARTS LIST

UNLESS OTHERWISE SPECIFIED

ALL MACHINED SURFACES 125 √

RIVET BASIC CODE-NAS523

BB—MS20426AD

BJ—MS20470AD

SEE 0-70814 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES		
.X	.XX	.XXX
± .1	± .03	± .010

ANGULAR PER 0-70802

MATL

PROD. ENGR

SECURITY CLASSIFICATION

CHECK

STRESS

GR ENGR

DESIGN M STREET 7/30/

DRAWN

CONTRACT NO.

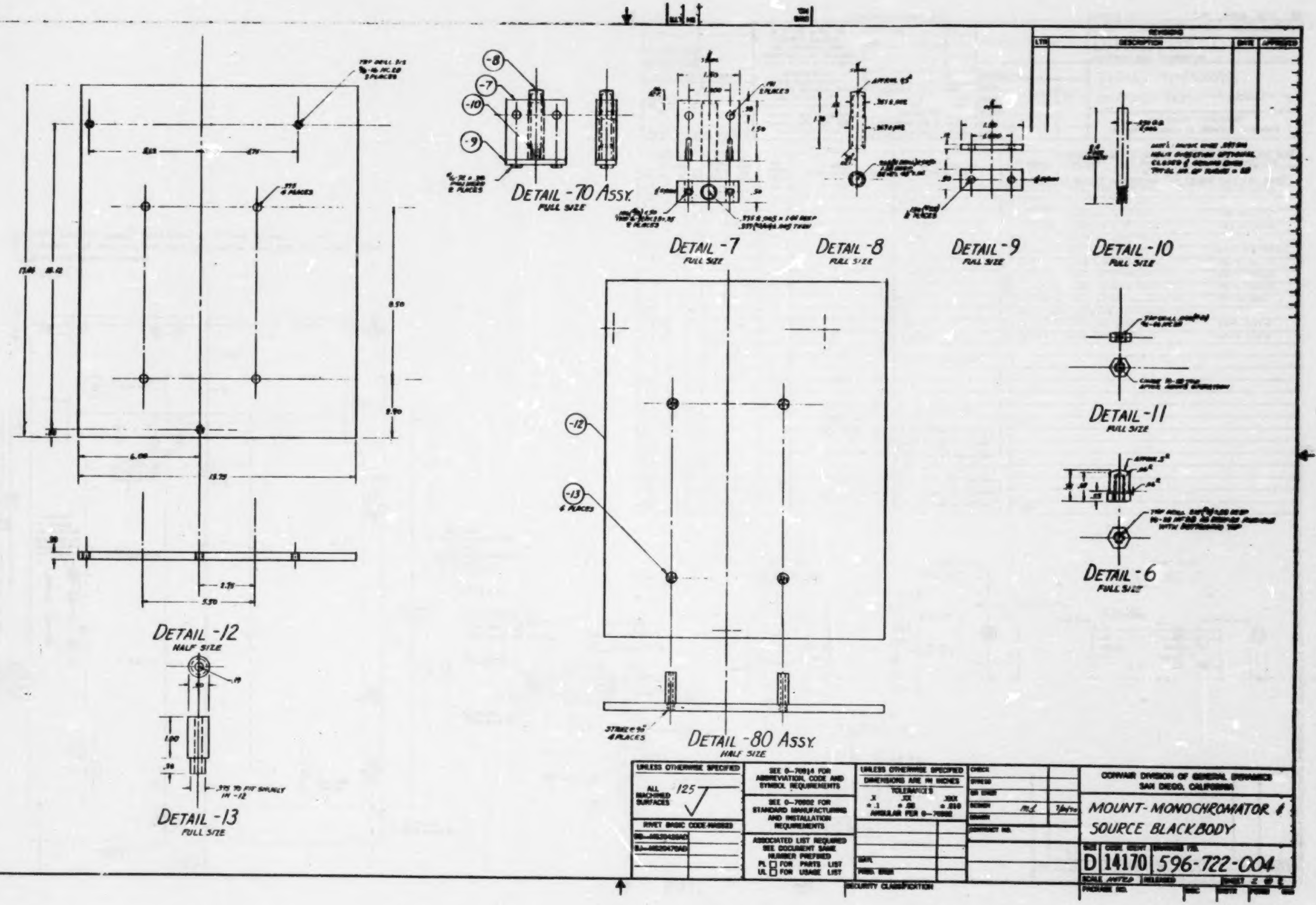
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

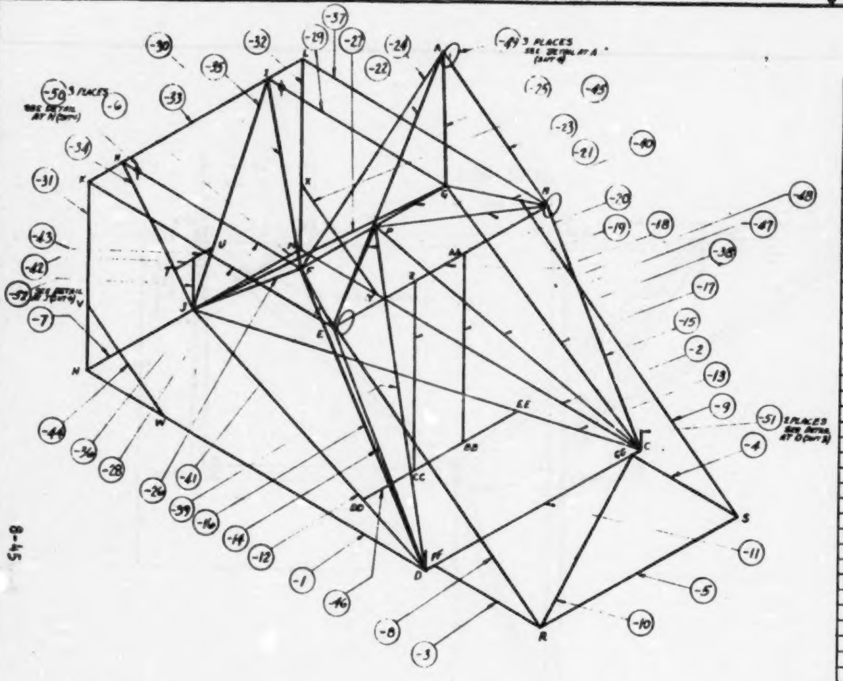
MOUNT - MONOCHROMATOR &
SOURCE BLACKBODY

SIZE	CODE IDENT	DRAWING NO.
D	14170	596-722-004

SCALE 1/2 & NOTED RELEASED SHEET 1 OF 2

PACKAGE NO. DEC DISTR FORM


DETAIL -70 ASSY.
FULL SIZE
-8
-7
-10
-9
DETAIL -7
FULL SIZE
DETAIL -8
FULL SIZE
DETAIL -9
FULL SIZE
DETAIL -10
FULL SIZE
DETAIL -11
FULL SIZE
DETAIL -6
FULL SIZE
DETAIL -12
HALF SIZE
DETAIL -13
FULL SIZE
DETAIL -80 ASSY.
HALF SIZE
-12
-13
4 PLACES
STAKE @ 90°
4 PLACES
1.50
.50
5.50
2.75
6.00
13.75
8.50
1.00
.20
REVISIONS
LTR
DESCRIPTION
DATE
APPROVED
UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES
125
RIVET BASIC CODE-MA0523
SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS
SEE 0-70802 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS
ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ±.1
.XX ±.03
.XXX ±.010
ANGULAR PER 0-70802
CHECK
STRESS
DRAWN
CONTRACT NO.
SECURITY CLASSIFICATION
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA
MOUNT-MONOCHROMATOR & SOURCE BLACKBODY
SIZE
D
CODE IDENT
14170
DRAWING NO.
596-722-004
SCALE NOTED
RELEASED
SHEET 2 OF 2
PACKAGE NO.



NOTES

1. BREAK ALL SHARP CORNERS.
2. FILLER MATERIAL SHALL BE 4043 OR 5356.
3. UNLESS OTHERWISE INDICATED, 1/16 FILLET WELD ALL AROUND.
4. WELDS ON PLANES DEKN, CBLM, KLMN, BEKL, BERS, E(FF)R AND B(GG)S SHALL BE FLUSH WITH OUTER SURFACE.
5. THE FRONT SURFACES OF -49 PADS SHALL LIE IN A PLANE ±.001 OVER ANY ONE PAD.
6. SHEET 2 SHOWS DIMENSIONAL LOCATION OF MEMBERS.
7. SHEET 3 SHOWS DETAILS AT JOINTS R, E, N, K AND D. JOINTS AT S, B M, L AND C OPPOSITE HAND EXCEPT FOR CR.
8. SHEET 4 SHOWS DETAILS AT JOINTS H, A, J, Z, CC AND DD. JOINTS AT I, BB AND EE OPPOSITE HAND EXCEPT FOR FI.
9. SHEET 5 SHOWS DETAILS AT JOINTS F, P, V AND W. JOINTS AT G, X AND Y OPPOSITE HAND EXCEPT FOR FI.
10. NO WELD MATERIAL SHALL EXTEND ABOVE THE TOP SURFACE OF -50 OR IN FRONT OF FRONT SURFACE OF -49.
11. ALL MEMBER CENTERLINES INTERSECT AT LETTERED JOINTS EXCEPT MEMBERS ER AND BS WHOSE CENTERLINES PASS 1.0 BELOW THE CENTERLINE OF BE IN THE PLANE ABE AS SHOWN ON SHEET 2.
12. STRESS RELIEVE 450°F ± 10° FOR 1.5 HRS AFTER WELDING. COOLING NEED NOT BE CONTROLLED.
13. PLANE DETERMINED BY TOP SURFACES OF -50 TO BE PERPENDICULAR TO PLANE DEFINED BY FRONT SURFACES OF -49 WITHIN 0°-10'.

PARTS LIST

REQ PER ASSY / INSTL	UNIT OF MEAS	ITEM OR FIND NO.	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT
1				-52	REAR FOOT TUBE	1 x 1 SQ x 8 LONG BAR 6061-T6511 ALUM. QQ-A-200/8
2				-51	FRONT FOOT TUBE	1 x 1 SQ x 4 LONG BAR 6061-T6511 ALUM.
3				-50	MONOCHR. MTG PAD	0.62 OD x 3 LONG ROD 6061-T6511 ALUM.
3				-49	TELESCOPE MTG PAD	2.00 O.D. x 3 LONG ROD 6061-T6511 ALUM.
1				-48	FRAME MEMBER E-(CC)	1 x 1 SQ. x 21 SQ. TUBE x .125 WALL 6063-T5 ALUM. QQ-A-200/9
1				-47	(AA)-(BB)	21
1				-46	(DD)-(EE)	22
1				-45	X-Y	14 BAR 6061-T6511 ALUM. QQ-A-200/8
1				-44	V-W	14 " " " " "
1				-43	G-U	6 SQ TUBE x .125 WALL 6063-T5 ALUM. QQ-A-200/9
1				-42	T-G	6
1				-41	E-F	11
1				-40	B-G	11
1				-39	D-P	25
1				-38	C-P	25
1				-37	B-L	31
1				-36	E-K	31
1				-35	I-J	24
1				-34	H-J	24
1				-33	K-L	17
1				-32	L-M	22
1				-31	K-N	22
1				-30	F-I	29
1				-29	G-I	24
1				-28	F-H	24
1				-27	G-J	32
1				-26	F-J	32
1				-25	A-G	27
1				-24	A-F	27
1				-23	A-B	27
1				-22	A-E	27
1				-21	F-G	20
1				-20	B-P	17
1				-19	E-P	17
1				-18	E-B	27
1				-17	C-G	29
1				-16	D-F	29
1				-15	C-B	24
1				-14	D-E	24
1				-13	C-J	44
1				-12	D-J	44
1				-11	FF-GG	27
1				-10	GG-R	30
1				-9	B-S	25
1				-8	E-R	25
1				-7	J-N	15
1				-6	J-M	15
1				-5	R-S	27
1				-4	GG-S	15 BAR 6061-T6511 ALUM. QQ-A-200/8
1				-3	FF-R	15 " " " " "
1				-2	C-M	42 SQ. TUBE x .125 WALL 6063-T5 ALUM QQ-A-200/9
1				-1	D-N	42 " " " " " "
60						

UNLESS OTHERWISE SPECIFIED

ALL MACHINED SURFACES 125 √

RIVET BASIC CODE-MA8523

SEE 0-70014 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70002 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT BASE NUMBER PREFIXED UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES

X	XX	XXX
± .1	± .03	± .010

ANGULAR PER 0-70000

SECURITY CLASSIFICATION

DRAWN M. STREEPY 7/11/60

Est. Wt -60Assy 50

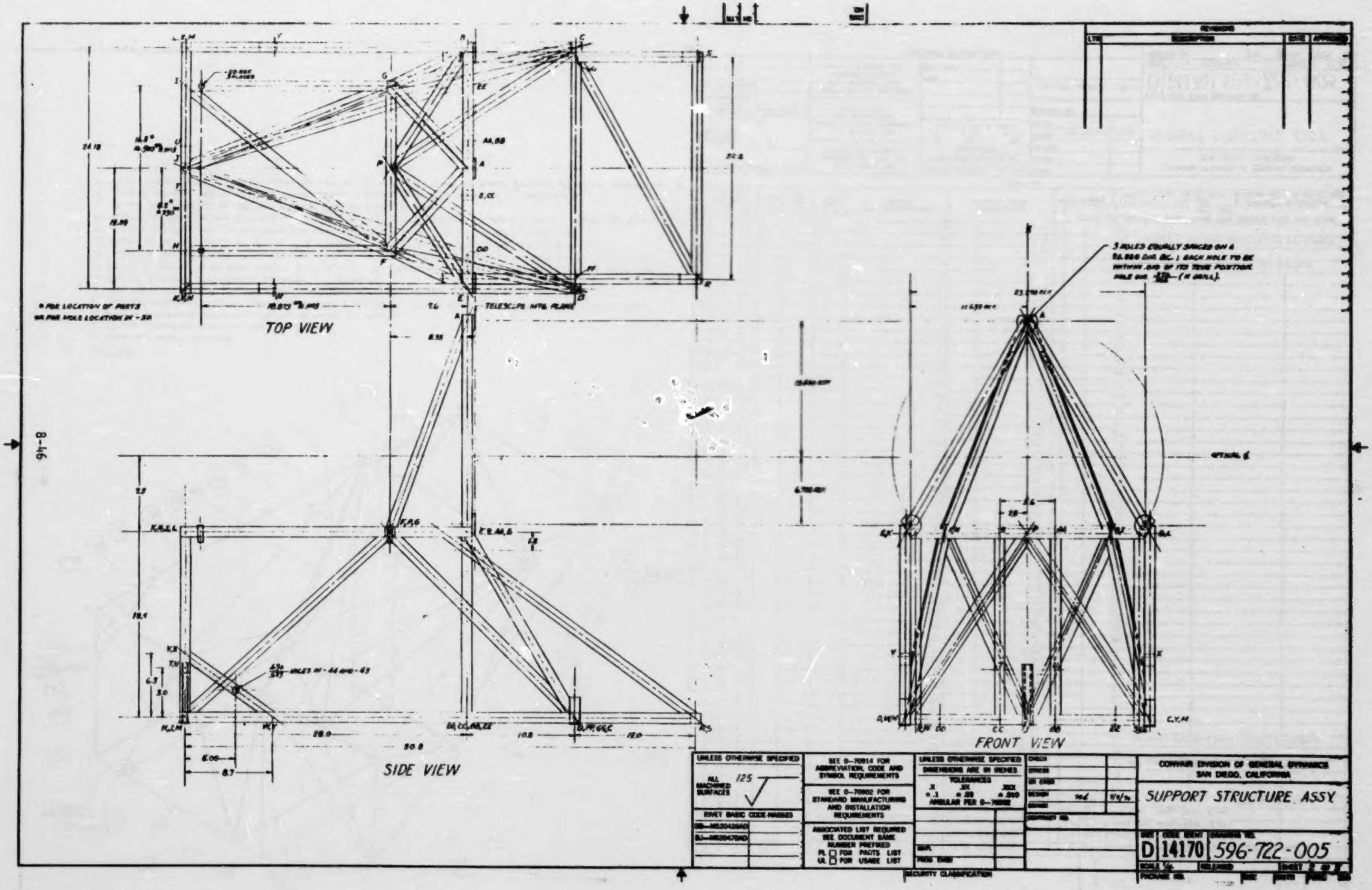
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

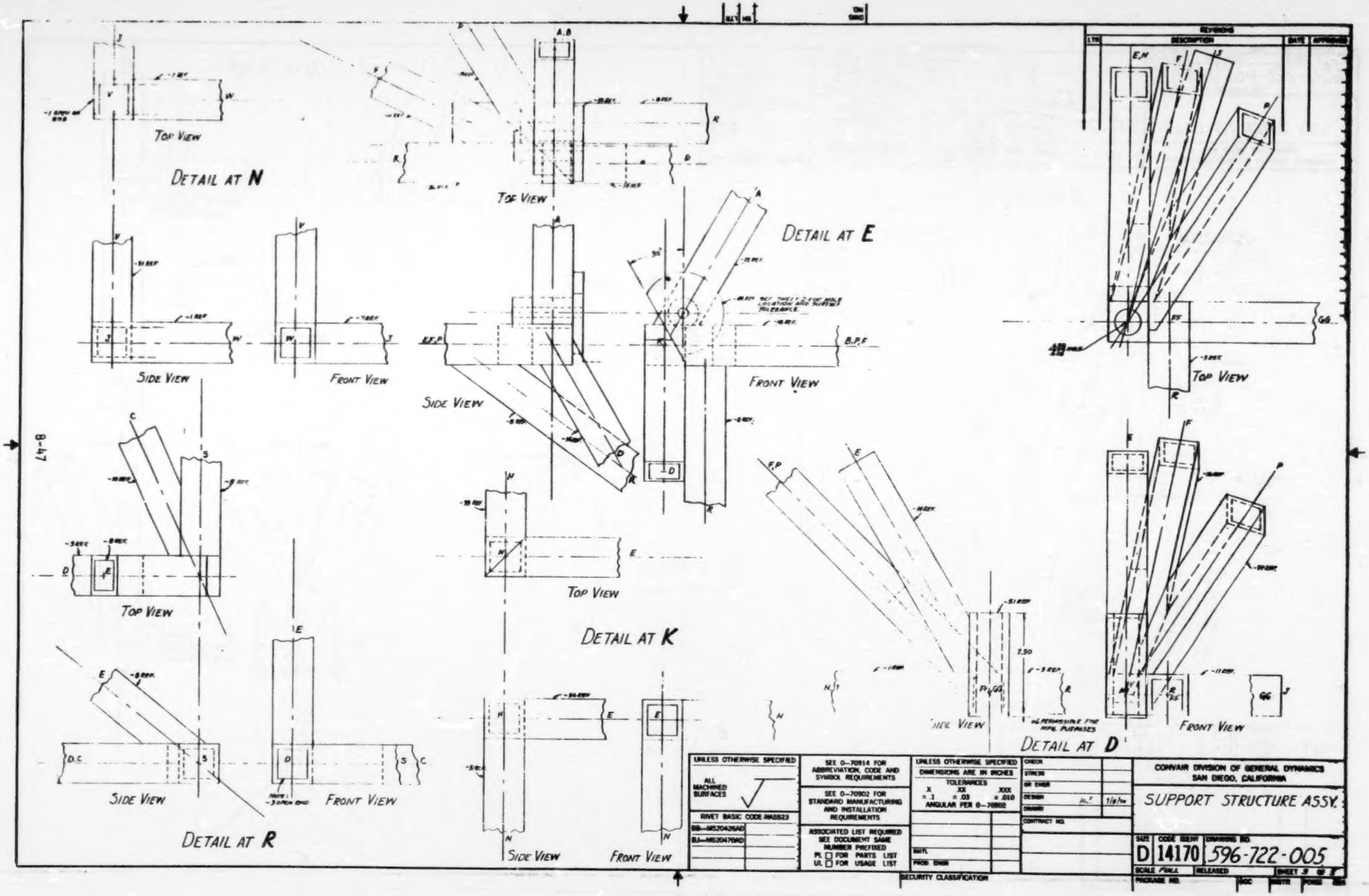
SUPPORT STRUCTURE ASSY.

D 14170 596-722-005

SCALE 1" = 5"

SHEET 1


TOP VIEW
SIDE VIEW
FRONT VIEW
TELESCOPE MTG. PLANE
3 HOLES EQUALLY SPACED ON A
DIA. B.C. ; EACH HOLE TO BE
WITHIN .010 OF ITS TRUE POSITION
UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125
RIVET BASIC CODE-MAS
SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS
SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS
ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
.X ±.1
.XX ±.03
.XXX ±.010
ANGULAR PER 0-70902
CHECK
STRESS
DESIGN
CONTRACT NO.
SECURITY CLASSIFICATION
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA
SUPPORT STRUCTURE ASSY
D
14170
596-722-005
SCALE
RELEASED
SHEET
SIDE VIEW dimensions: 7.5, 18.5, 6.3, 5.0, 6.00, 8.7, 28.0, 50.8, 10.8, 12.0
TOP VIEW dimensions: 24.18, 7.6, 8.35, 32.8



CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

SUPPORT STRUCTURE ASSY.

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES √
RIVET BASIC CODE-MA5523
BB—MS20426AD
BJ—MS20470AD

SEE 0—70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0—70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES

X	XX	XXX
± .1	± .03	± .010

ANGULAR PER 0—70902

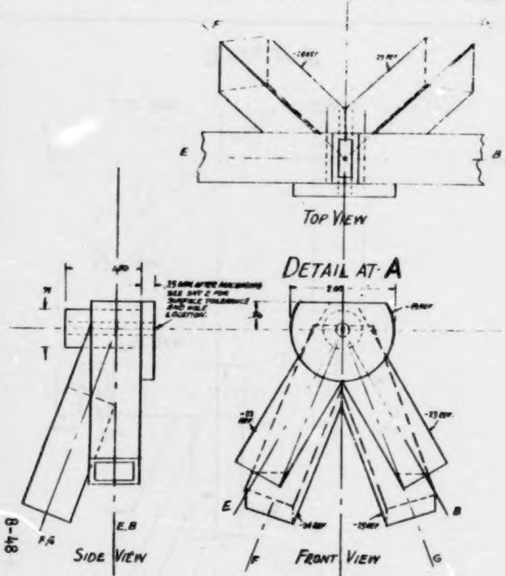
MATL
PROD ENGR

CHECK
STRESS
GR ENGR
DESIGN
DRAWN
CONTRACT NO.

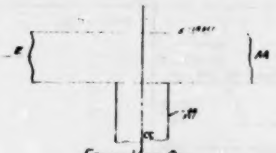
SIZE D
CODE IDENT 14170
DRAWING NO. 596-722-005
SCALE FULL
RELEASED
SHEET 3 OF 3
PACKAGE NO.

SECURITY CLASSIFICATION

REVISIONS
LTR | DESCRIPTION | DATE | APPROVED

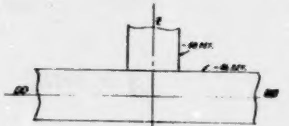

F
E
B
Top View
Side View
E,B
F,G
.25 MIN AFTER MACHINING SEE SHT 2 FOR SURFACE TOLERANCE AND HOLE LOCATION
2.00
E
F
G
B
Front View

DETAIL AT A



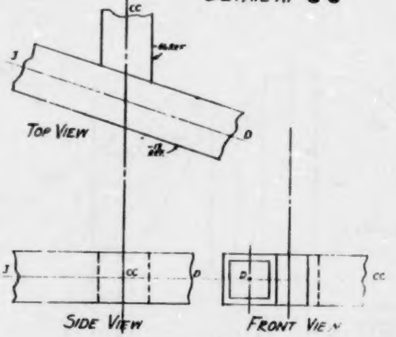
FRONT VIEW ONLY

DETAIL AT Z

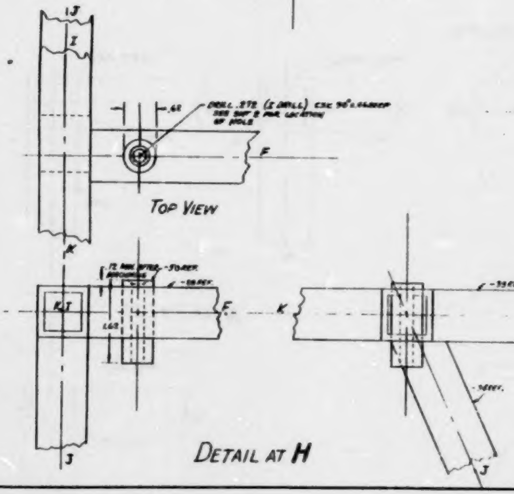


FRONT VIEW ONLY

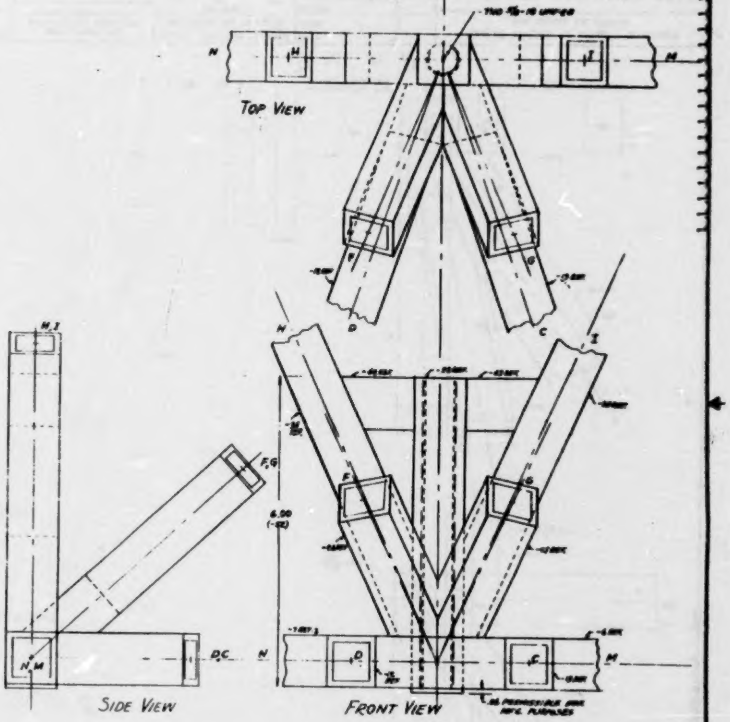
DETAIL AT CC



DETAIL AT DD



DETAIL AT H



DETAIL AT J

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125 √
RIVET BASIC CODE-NAS523
BB—MS20426AD
BJ—MS20470AD

SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST

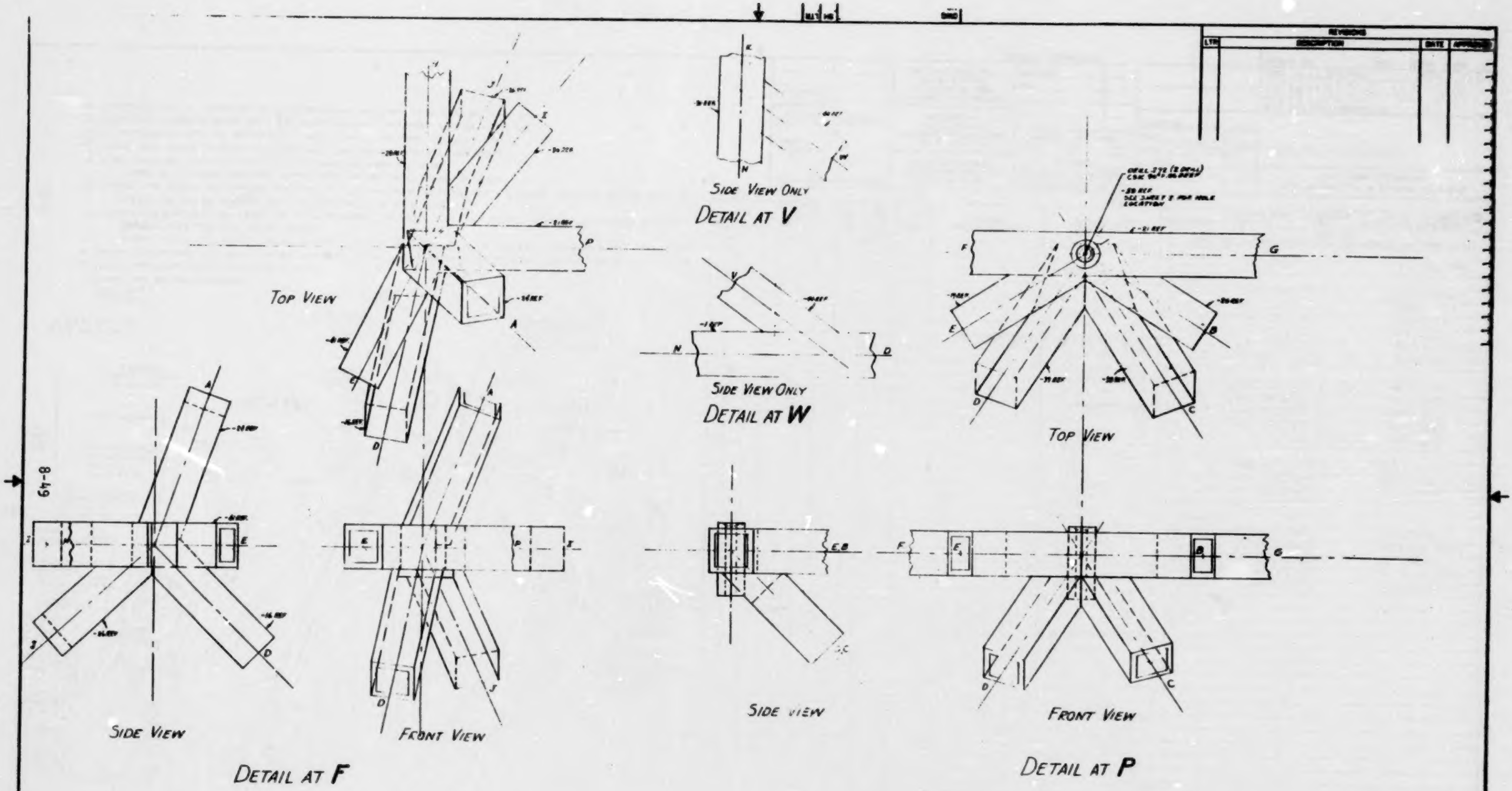
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ±.1 | .XX ±.03 | .XXX ±.010
ANGULAR PER 0-70902

CHECK
STRESS
GR ENGR
DESIGN
DRAWN
CONTRACT NO.
SECURITY CLASSIFICATION

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

SUPPORT STRUCTURE ASSY.

SIZE D | CODE IDENT 14170 | DRAWING NO. 596-722-005
SCALE | RELEASED | SHEET
PACKAGE NO.



DETAIL AT V

DETAIL AT W

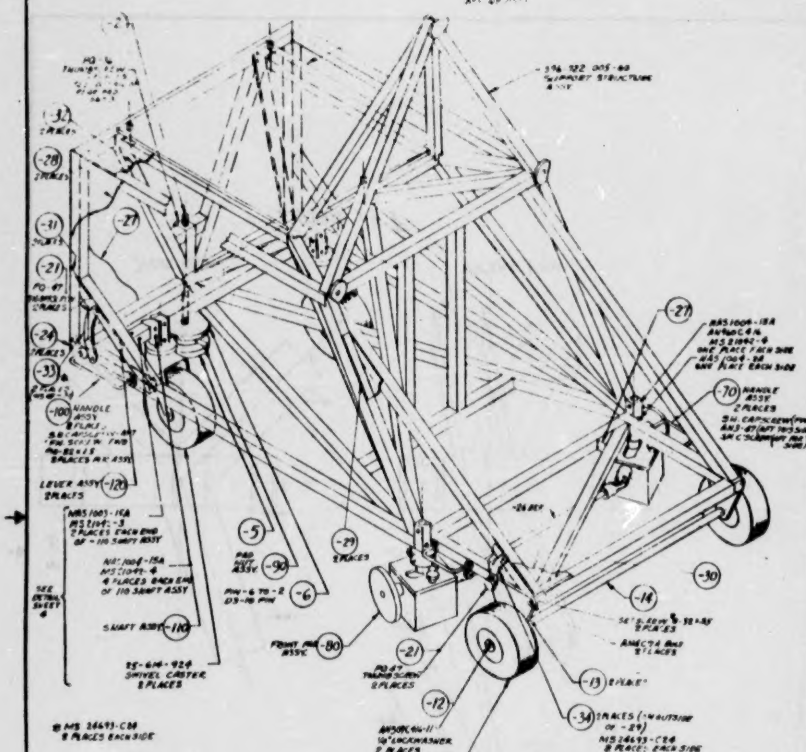
DETAIL AT F

DETAIL AT P

UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES 125 √ RIVET BASIC CODE NAS523	SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED PL ☐ FOR PARTS LIST UL ☐ FOR USAGE LIST	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES .X ±.1 .XX ±.03 .XXX ±.010 ANGULAR PER 0-70902	CHECK STRESS GR ENGR DESIGN Rud 7/10/70 DRAWN CONTRACT NO.	CONVAIR DIVISION OF GENERAL DYNAMICS SAN DIEGO, CALIFORNIA SUPPORT STRUCTURE ASSY

SIZE D CODE IDENT 14170 DRAWING NO. 596-722-005

SECURITY CLASSIFICATION


596-722-005-60 SUPPORT STRUCTURE ASSY
-27
-28 2 PLACES
-31 2 PLACES
-21
-24 2 PLACES
-33 2 PLACES
-100 HANDLE ASSY 2 PLACES
LEVER ASSY -120 2 PLACES
NAS1003-15A MS21042-3 2 PLACES EACH END OF -110 SHAFT ASSY
NAS1004-15A MS21042-4 4 PLACES EACH END OF 110 SHAFT ASSY
SHAFT ASSY -110
25-614-924 SWIVEL CASTER 2 PLACES
-5
PAD NUT ASSY -90
-6
-29 2 PLACES
FRONT PAD ASSY -80
-21 THUMBSCREW 2 PLACES
-12
-14
-30
-27
-70 HANDLE ASSY 2 PLACES
-13 2 PLACES
-34 2 PLACES (-14 OUTSIDE OF -29) MS24693-C24 8 PLACES EACH SIDE
4-6-92 WHEEL 2 PLACES
1/4" LOCKWASHER 2 PLACES
MS 24693-C24 8 PLACES EACH SIDE
SEE DETAIL SHEET 4

NOTES:

1. BREAK ALL SHARP CORNERS.
2. FILLER MATERIAL SHALL BE 4043 OR 5356.
3. PANEL DIMENSIONS (-27 THRU -32) ARE NOMINAL. TRIM PANELS UPON INSTALLATION. ATTACH PANELS TO FRAME EVERY 6 INCHES APPROX. WITH #6 SELF TAPPING PAN HEAD SCREWS. PREDRILL .10 (#36 DRILL). LAP HORIZ. PANELS OVER VERTICAL PANEL EDGES.
4. -33 AND -34 RUBSTRIP THICKNESS TO BE DETERMINED ON INSTALL. ALLOW ABOUT .005-.010 CLEARANCE. ATTACH -33 & -34 AFTER INSTALL. OF -120 ASSY AND -13 RESPECTIVELY.
5. ADJUST -26 LENGTH IN U-JOINTS SO THAT A LINE PARALLEL TO SIDES OF -7 FRONT PAD FOOT IS TANGENT TO EDGE OF -5 REAR PAD FOOT. ALIGN INNER HALVES OF U-JOINTS ON -26.
6. BLACK ANODIZE PARTS LISTED BY G IN NOTE SYMBOL COLUMN.
7. PRIME AND PAINT PANELS -27 THRU -32 TO MATCH SAMPLE PROVIDED.
8. IT IS PERMISSIBLE TO SUBSTITUTE 2024 MATERIAL FOR -27 THRU -32.
9. RECEIVER STAND IS STAND NO. 1 (FOR TELESCOPE NO. 1) AND USES 596-722-004-90
10. SOURCE STAND IS STAND NO. 2 (FOR TELESCOPE NO. 2) AND USES 596-722-004-60

— CONTINUED ON SHEET 3 —

120	110	100	90	80	70	-2	UNIT OF MEAS	ITEM OR FIND NO	CODE IDENT NO	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	NOTE	(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT	
						1				AN[illegible] 67	#10 32 x 0.5 BOLT		THREAD FOR .68 LENGTH.	
						1				-28	BLOCK		1 x 1 x 2.0 6061-T6511 ALUM BAR	QQ-A-200/8
						[illegible]				-[illegible]	HANDLE ASSY.			
						2				AN[illegible] 78	1/4 28 x [illegible] NUT		C.F.E.	
						10				[illegible]	1/4-20 BOLT		C.P.S.	
						10				[illegible]-4	1/4-28 [illegible] LOCKING NUT		C.A.	
						2				[illegible]	6 [illegible] FH SCREW		C.P.S.	
						4				[illegible]	10-32 x .75 BOLT		C.P.S.	
						4				MS[illegible]-3	10-32 SELF LOCKING NUT		C.P.S.	
						1				596-722-005-60	SUPPORT STRUCTURE ASSY			
						1				596-722-004-60-90	MOUNT [illegible]			
						2				4-6-92	WHEEL - 6 DIA x 2 WIDE		COLSON CO. 3900 [illegible]	
						2				25-614-924 [illegible]	SWIVEL CASTER - 6 DIA x 2 WHEEL		" " " "	
		1			1					HA-3	HANDLE (303 ST. STL.)		W.M. BERG INC. 499 OCEAN AVE. EAST ROCKAWAY L.I.N.Y. 11518	
				4						PQ-46	THUMBSCREW 1/4-20 x 1 [illegible]		" " "	
						4				PQ-47	" " x 1 3/8 LG		" " "	
				2						CNI-18	HAND WHEEL		" " "	
						1				D3-10	[illegible] DOWEL PIN		" " "	
						2				PQ-36	THUMBSCREW 10-32 x [illegible] LG		" " "	
				2						UJ-6	UNIVERSAL JOINT [illegible]		" " "	
						1				-80	FRONT PAD ASSY			
						1				-90	PAD NUT ASSY	G		
						2				-100	HANDLE ASSY			
						1				-110	SHAFT ASSY			
						2				-120	LEVER ASSY			
				12						NAS1351C3-8	HEX SOCKET HEAD CAPSCREW		#10-32 x .5 LONG	
						4				NAS1351C3-24	" " " "		#10-32 x 1.5 LONG	
						2				[illegible]565A-8-12	" " " SETSCREW		#8-32 x .75 LONG	
				2							WASHER		AN960-C816	
				1						-26	TIE ROD		.50 DIA. x 10 321 COND A ST STL BAR	QQ-S-763 COND [illegible]
		2			2					-25	WASHER		.125 x 1.6 x 1.5 302 COND A ST STL [illegible]	MIL-S-5059 COND [illegible]
						2				-24	BLOCK		.75 x .75 x 9.0 6061-T6511 ALUM. BAR	QQ-A-200/8
1										-23	SHAFT, LEVER		.50 DIA x 8.5 321 COND A ST STL BAR	QQ-S-763 - COND [illegible]
			2							-22	ROD, HANDLE		.38 DIA x 5.0 6061-T6511 ALUM. ROD	QQ-A-200/8
				4		2				-21	SPACER	G	0.50 DIA x .5 " "	"
				4						-20	WASHER		MODIFY FROM AN960-C716	
	2									-19	SHAFT END		1 x 1 x 3.0 6061-T6511 ALUM. BAR	QQ-A-200/8
1										-18	LEVER		.25 x 1.5 x 6.0 302 COND A ST STL PLATE	MIL-S-5059 COND [illegible]
	2									-17	PLATE		.125 x [illegible] 3.0 6061-T651 ALUM. PLATE	QQ-A-250/11
	4									-16	PLATE, SIDE		.125 x 2.5 x 3.0 " " "	"
	1									-15	SHAFT		1.0 x 1.50 x .125 WALL x 23 6063-T5 ALUM. TUBE	QQ-A-200/9
						1				-14	AXLE		.625 DIA x 3.0 6061-T6511 ALUM. ROD	QQ-A-200/8
						2				-13	FRONT WHEEL PLATE	G	.38 x [illegible] x 7.0 6061-T651 ALUM. PLATE	QQ-A-250/11
						2				-12	WASHER		.125 x 1.5 x 1.5 6061-T6 ALUM. PLATE	QQ-A-250/11
				2						-11	CLAMP PLATE	G	.312 x 4.5 x 4.5 6061-T651 ALUM. PLATE	QQ-A-250/11
				4						-10	SCREW MTG PLATE	G	.375 x 1.5 x 3.0 " "	"
				2						-9	LATERAL ADJ. SCREW		.625 DIA x 7.0 321 COND A ST STL ROD	QQ-S-763 COND [illegible]
				2						-8	FRONT PAD SLIDER		2 x 2 x 2.5 BRASS [illegible] ROD	QQ-B-626 COMP [illegible]
				2						-7	FRONT PAD FOOT	G	4.0 DIA x 6.0 2024-[illegible] ALUM. BAR	QQ-A-200/3
						1				-6	ELEVATION WHEEL	G	.50 x 5.0 x 5.0 6061-T651 ALUM. PLATE	QQ-A-250/11
						1				-5	REAR PAD FOOT	G	1.5 x 5.0 x 5.0 2024-T3 ALUM. PLATE	QQ-A-250/4
			1							-4	PAD NUT		2.0 DIA x 1.5 6061-T6511 ALUM. BAR	QQ-A-200/8
				2						-3	PAD NUT	G	2.0 DIA x 1.5 " " "	"
						1				-2	REAR PAD BALL ROD		.75 DIA x 13.0 321 COND A ST STL [illegible]	QQ-S-763 [illegible]
				2						-1	FRONT PAD BALL ROD		.75 DIA x 5.0 "	"

REQ PER ASSY / INSTL

PARTS LIST

UNLESS OTHERWISE SPECIFIED

ALL MACHINED SURFACES 125 √

RIVET BASIC CODE NAS523

SEE 0-70014 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70002 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT BASE NUMBER PREFIXED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES X ±.1 XX ±.03 XXX ±.010

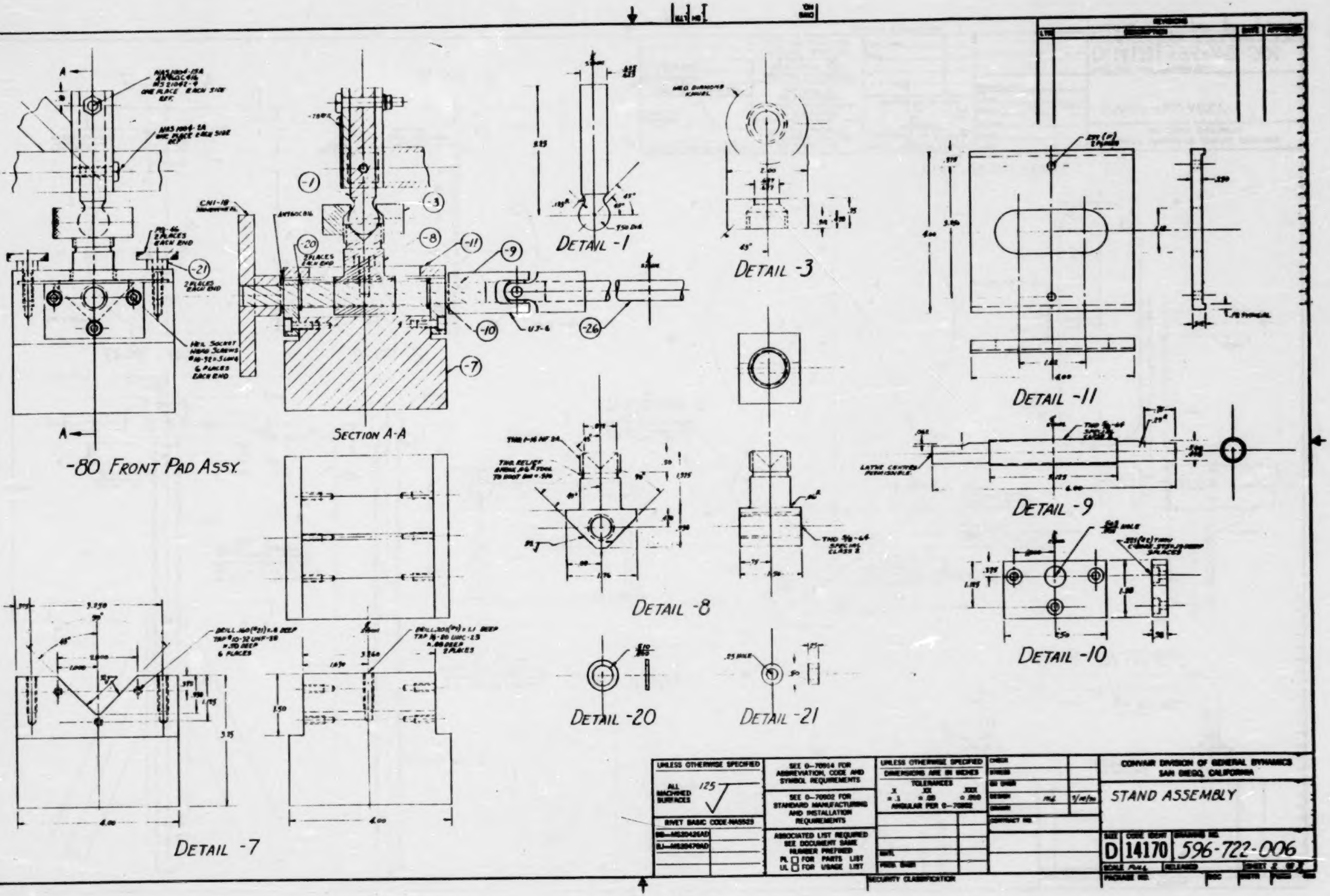
M. STREIFF

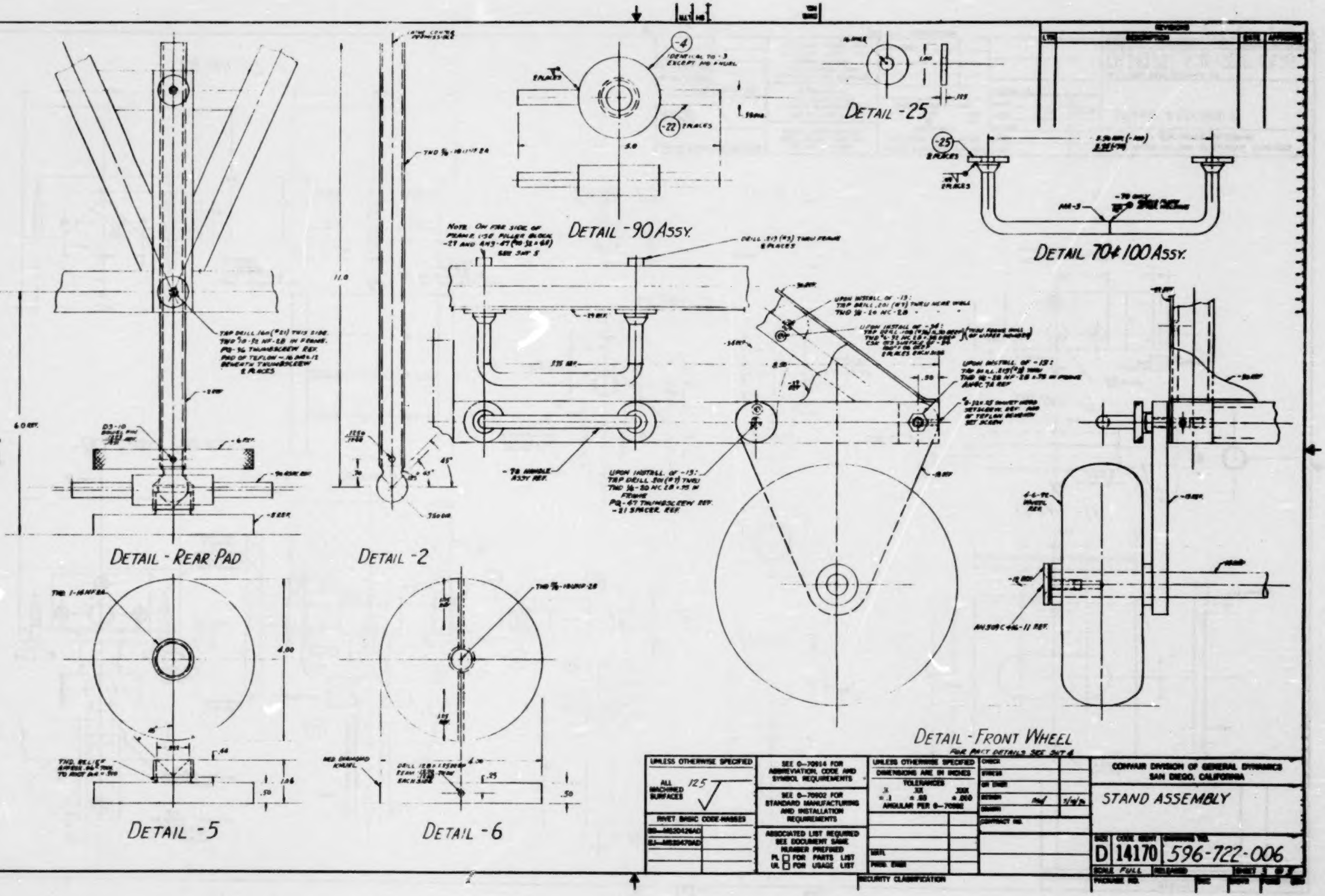
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

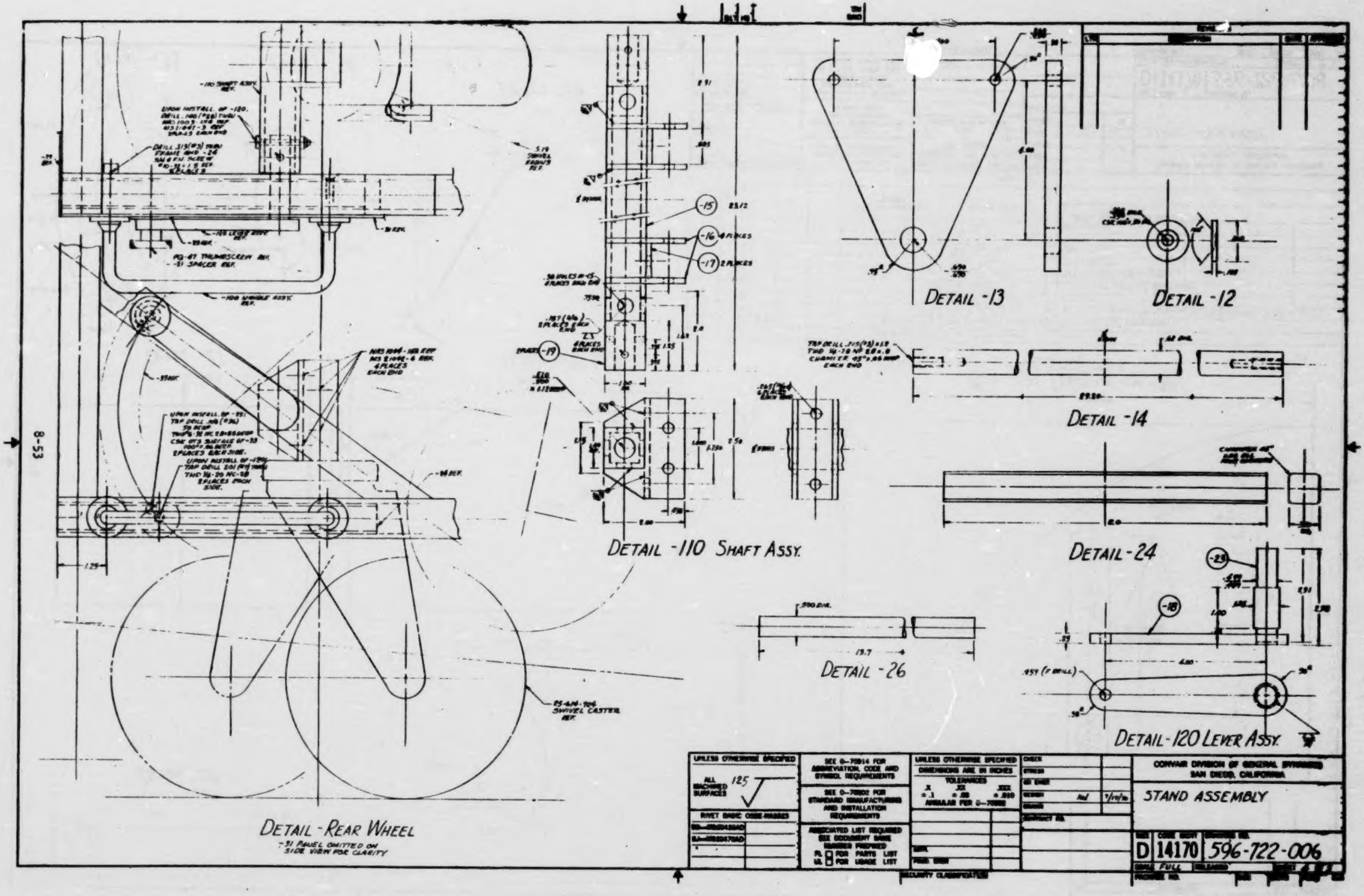
STAND ASSEMBLY

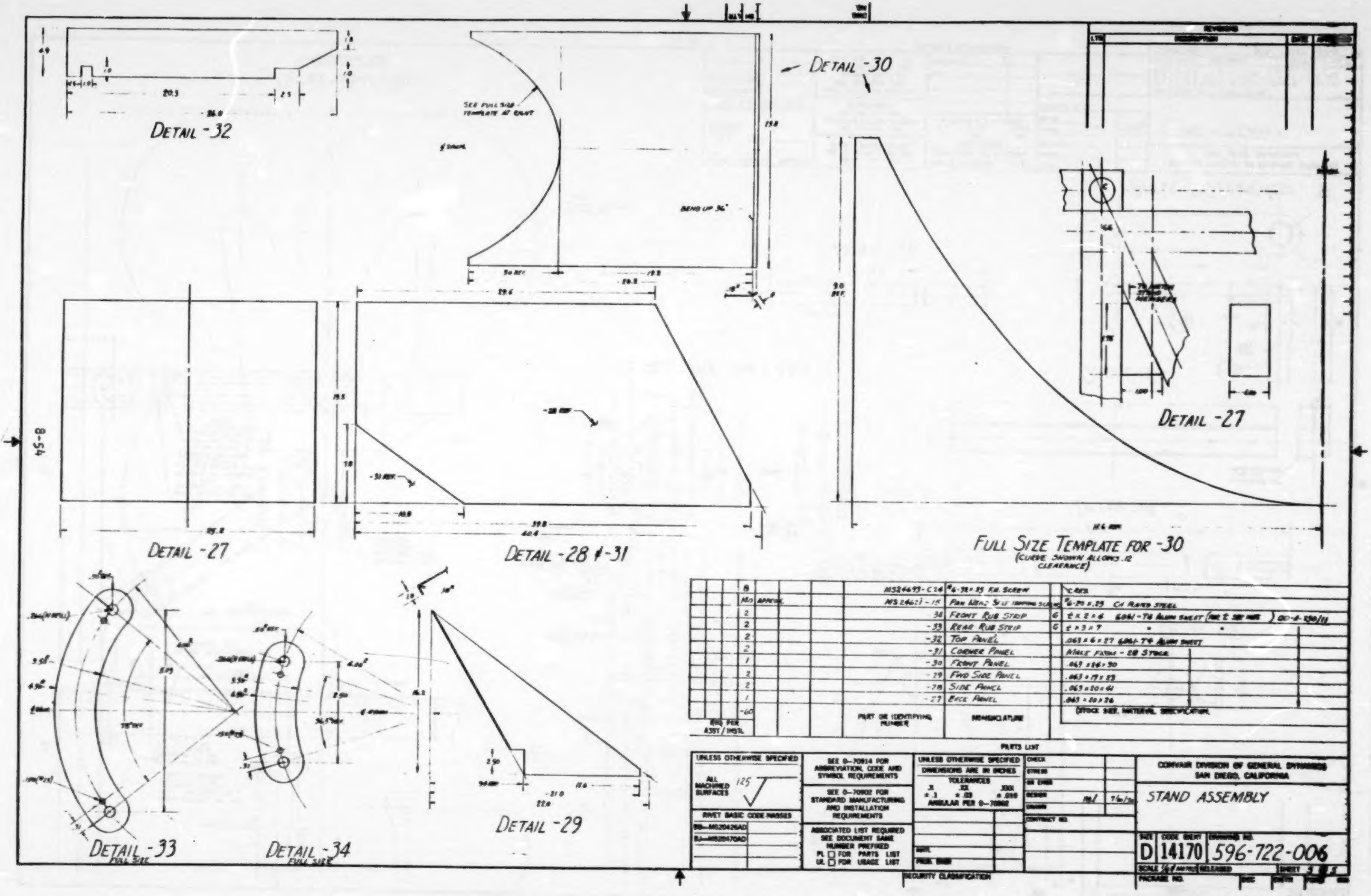
D 14170 596-722-006

SECURITY CLASSIFICATION

-80 FRONT PAD ASSY.
A
A
MS21042-4 ONE PLACE EACH SIDE REF.
NAS 1004-5A ONE PLACE EACH SIDE REF.
PD-4L 2 PLACES EACH END
-21
2 PLACES EACH END
HEX SOCKET HEAD SCREWS #10-32 x .5 LONG 6 PLACES EACH END
CN1-18
ANTISOC 816
-20
2 PLACES EACH END
-1
-3
-8
-11
-9
-10
U7-6
-26
-7
SECTION A-A
DETAIL -1
DETAIL -3
DETAIL -11
DETAIL -9
DETAIL -10
DETAIL -8
DETAIL -20
DETAIL -21
DETAIL -7
LATHE CENTER PERMISSIBLE
MED DIAMOND KNURL
4.00
UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125
RIVET BASIC CODE-NAS523
BB—MS20426AD
BJ—MS20470AD
SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS
SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS
ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
.X ±.1
.XX ±.03
.XXX ±.010
ANGULAR PER 0-70902
CHECK
STRESS
GR ENGR
DESIGN
DRAWN
CONTRACT NO.
MATL
PROD. BASIS
SECURITY CLASSIFICATION
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA
STAND ASSEMBLY
SIZE D
CODE IDENT 14170
DRAWING NO. 596-722-006
SCALE
RELEASED
SHEET 2
PACKAGE NO.


DETAIL - REAR PAD
DETAIL -2
DETAIL -90 ASSY.
DETAIL -25
DETAIL 70 & 100 ASSY.
DETAIL -5
DETAIL -6
DETAIL - FRONT WHEEL
FOR PART DETAILS SEE SHT 4
TAP DRILL .160 (#21) THIS SIDE. THD 10-32 NF-2B IN FRAME. PQ-56 THUMBSCREW REF. PAD OF TEFLON -16 DIA x 1/2 BENEATH THUMBSCREW 2 PLACES
NOTE: ON FAR SIDE OF FRAME USE FILLER BLOCK -27 AND AN3-47 (10-32 x 4.8) SEE SHT 5
DRILL .213 (#3) THRU FRAME 2 PLACES
UPON INSTALL OF -13: TAP DRILL .201 (#7) THRU NEAR WALL THD 1/4-20 NC-2B
UPON INSTALL OF -13: TAP DRILL .201 (#7) THRU THD 1/4-20 NC-2B x .75 IN FRAME PQ-47 THUMBSCREW REF. -21 SPACER REF.
-78 HANDLE ASSY REF.
4-6-9C WHEEL REF.
AN310C-6G-11 REF.
THD 1-14NF-2A
THD 5/8-18UNF-2B
THD 5/8-18UNF-2A
MED DIAMOND KNURL
4.00
.50
6.0 REF.
11.0
5.0
45°
-4
IDENTICAL TO -3 EXCEPT NO KNURL
-22 2 PLACES
-25 2 PLACES
UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125
RIVET BASIC CODE-MA5593
BD—MS20426AD
DJ—MS20470AD
SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS
SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS
ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES .X ±.1 .XX ±.03 .XXX ±.010
ANGULAR PER 0-70902
CHECK
STRESS
GR ENGR
DESIGN
DRAWN
CONTRACT NO.
MATL
PROJ. ENGR
SECURITY CLASSIFICATION
CONVAIR DIVISION OF GENERAL DYNAMICS SAN DIEGO, CALIFORNIA
STAND ASSEMBLY
SIZE D
CODE IDENT 14170
DRAWING NO. 596-722-006
SCALE FULL
RELEASED
SHEET 3
PACKAGE NO.
REVISIONS
LTR
DESCRIPTION
DATE
APPROVED


DETAIL - REAR WHEEL
-31 PANEL OMITTED ON SIDE VIEW FOR CLARITY
-110 SHAFT ASSY. REF.
UPON INSTALL OF -100, DRILL .140 (#28) THRU MS51001-3 REF. 2 PLACES EACH END
DRILL .213 (#3) THRU FRAME AND -24
-100 LEVER ASSY. REF.
PG-47 THUMBSCREW AN. -31 SPACER REF.
-100 HANDLE ASSY. REF.
5.19 SWIVEL RADIUS REF.
25-6M-906 SWIVEL CASTER REF.
1.25
DETAIL -110 SHAFT ASSY.
-15
-16 4 PLACES
-17 2 PLACES
-19
25.12
8.51
DETAIL -13
DETAIL -12
DETAIL -14
29.20
DETAIL -24
6.0
DETAIL -26
.500 DIA.
13.7
DETAIL -120 LEVER ASSY.
-23
-18
4.00
UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125
RIVET BASIC CODE-NAS523
SEE 0-70014 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS
SEE 0-70002 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS
ASSOCIATED LIST REQUIRED SEE DOCUMENT BASE NUMBER PREFIXED
PL FOR PARTS LIST
UL FOR USAGE LIST
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
.X ±.1
.XX ±.03
.XXX ±.010
ANGULAR PER 0-70002
CHECK
STRESS
DESIGN
CONTRACT NO.
SECURITY CLASSIFICATION
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA
STAND ASSEMBLY
SIZE D
CODE IDENT 14170
DRAWING NO. 596-722-006
SCALE FULL



REQ PER ASSY/INSTL	PART OR IDENTIFYING NUMBER	NOMENCLATURE		(STOCK SIZE, MATERIAL, SPECIFICATION)
8	MS24693-C24	#6-32 × .25 F.H. SCREW		CRES
No APPROX.	MS24621-15	PAN HEAD SELF TAPPING SCREW		#6-20 × .25 CD PLATED STEEL
2	-34	FRONT RUB STRIP	G	¼ × 2 × 4 6061-T6 ALUM SHEET (FOR ℄ SEE NOTE) QQ-A-250/11
2	-33	REAR RUB STRIP	G	¼ × 3 × 7
2	-32	TOP PANEL		.063 × 6 × 27 6061-T4 ALUM SHEET
2	-31	CORNER PANEL		MAKE FROM -28 STOCK
1	-30	FRONT PANEL		.063 × 26 × 30
2	-29	FWD SIDE PANEL		.063 × 17 × 23
2	-28	SIDE PANEL		.063 × 20 × 41
1	-27	BACK PANEL		.063 × 20 × 26
-60				

PARTS LIST

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125 √

RIVET BASIC CODE NAS523
BB—MS20426AD
BJ—MS20470AD

SEE 0–70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0–70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ±.1 .XX ±.03 .XXX ±.010
ANGULAR PER 0–70902

CHECK
STRESS
GR ENGR
DESIGN ml 7/6/70
DRAWN
CONTRACT NO.
APPD.
PROJ. ENGR

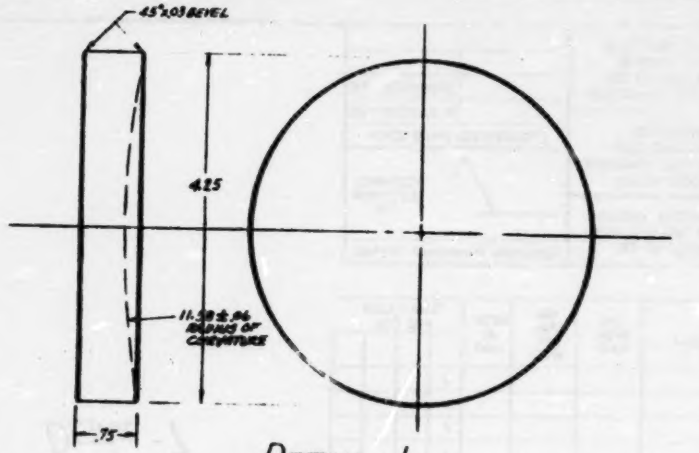
SECURITY CLASSIFICATION

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

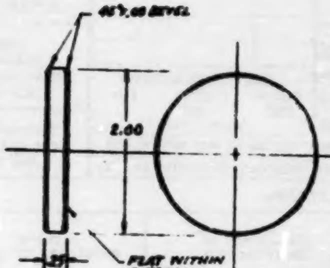
STAND ASSEMBLY

SIZE D
CODE IDENT 14170
DRAWING NO. 596-722-006
SCALE ½ | RELEASED | SHEET 5 OF 5
PACKAGE NO.

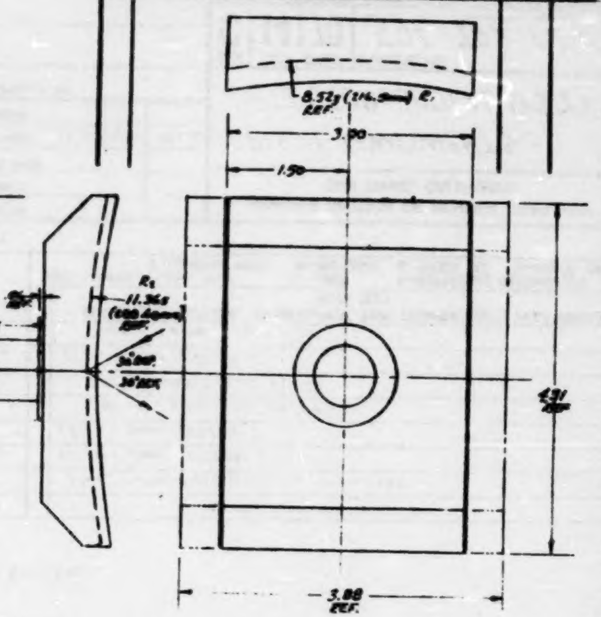
REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



DETAIL -1



DETAIL -2



DETAIL -3

TRIM EDGES AS SHOWN
BEVEL 45°x.03 ALL AROUND

NOTES:

1. SURFACE QUALITY OPTICAL SURFACES 60-40 OR BETTER (MIL-O-13830A)
2. OTHER SURFACES APPROX. 120 GRIT OR BETTER.
3. ALUMINIZE OPTICAL SURFACES OF -1 AND -2. OVERCOAT SiO λ/4 VISIBLE.
4. PROTECT SURFACE OF -3 DURING SAWING OPERATION.

REQ PER ASSY / INSTL				UNIT OF MEAS	ITEM OR FIND NO.	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT
			1				-3	TOROIDAL MIRROR	MAKE FROM PERKIN-ELMER 301-1006 (301-0017 ASSY)
			1				-2	FLAT DIAGONAL MIRROR	2.1 DIA x .3 ANNEALED PYREX
			1				-1	SPHERICAL MIRROR	4.38 DIA x .8 ANNEALED PYREX

NOTE SYMBOL: E—END ITEM G—GENERAL NOTE L—LIMIT M—MATERIAL R—REFERENCE DESIGNATION S—STOCK NO. U—USAGE DATA

PARTS LIST

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES √

RIVET BASIC CODE-NAS523
BB—MS20426AD
BJ—MS20470AD

SEE 0—70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0—70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES

.X	.XX	.XXX
±.1	±.03	±.010

ANGULAR PER 0—70902

MATL
PROD. ENGR

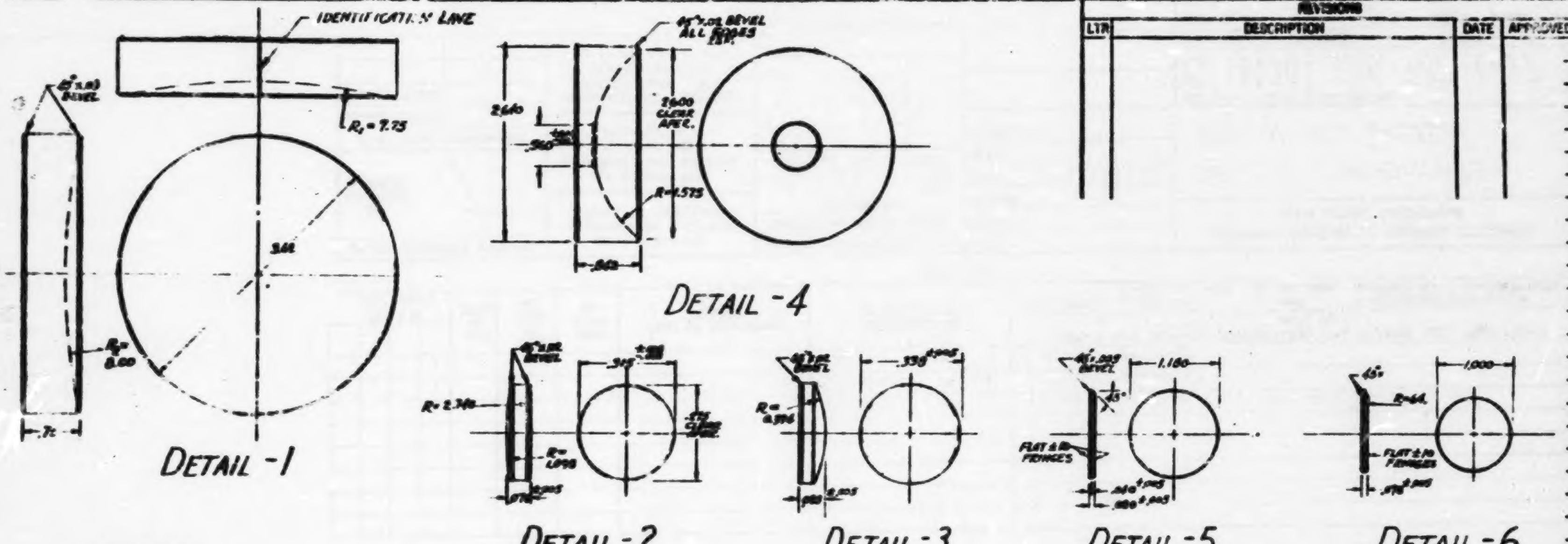
SECURITY CLASSIFICATION

CHECK		
STRESS		
GR ENGR		
DESIGN	M. STREIFF	8/3/70
DRAWN		
CONTRACT NO.		

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

OPTICAL COMPONENTS -
REF. OPTICS SYSTEM

SIZE C
CODE IDENT 14170
DRAWING NO. 596-722-007
SCALE FULL
RELEASED
SHEET 1 OF 1
PACKAGE NO.
DOC
DISTR
FORM 6013



DETAIL -1

DETAIL -4

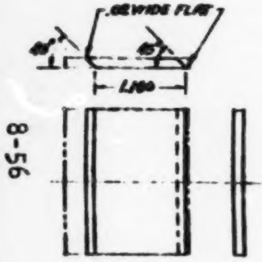
DETAIL -2
4X FULL SIZE

DETAIL -3
4X FULL SIZE

DETAIL -5

DETAIL -6

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



DETAIL -7

NOTES:
1. SURFACE QUALITY OPTICAL SURFACES 60-40 OR BETTER (MIL-O-13830A)
2. OTHER SURFACES APPROX 120 GRIT OR BETTER.
3. ALUMINIZE OPTICAL SURFACES OF -1, -3 & -4. OVERCOAT SiO λ/4 VISIBLE.

REQ PER ASSY / INSTL				UNIT OF MEAS	ITEM OR FIND NO.	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION		(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT
			1				-7	DIAGONAL MIRROR		MADE FROM PERKIN ELMER PIC-2335
			1				-6	ENTRANCE FIELD LENS		1.0 DIA × 3MM IRTRAN 2
			1				-5	WINDOW		1.5 DIA × 2MM IRTRAN-2
			1				-4	PRI. MIRROR		DIA.× ANNEALED PYREX
			1				-3	SEC. MIRROR		DIA.× ANNEALED PYREX
			1				-2	DETECTOR FIELD LENS		.75 DIA. × 2MM IRTRAN-2
			1				-1	TOROIDAL MIRROR		DIA.× ANNEALED PYREX

NOTE SYMBOL: E—END ITEM G—GENERAL NOTE L—LIMIT M—MATERIAL R—REFERENCE DESIGNATION S—STOCK NO. U—USAGE DATA

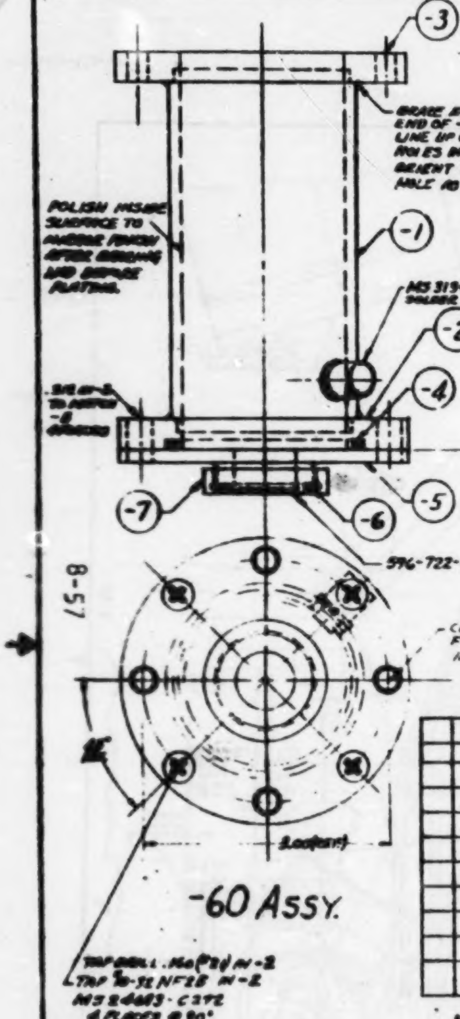
PARTS LIST

UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES √	SEE 0—70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES .X ±.1 .XX ±.03 .XXX ±.010 ANGULAR PER 0—70902	CHECK STRESS GR ENGR DESIGN M. STREIFF 8/4/70 DRAWN	CONVAIR DIVISION OF GENERAL DYNAMICS SAN DIEGO, CALIFORNIA
RIVET BASIC CODE-NAS523 BB—MS20426AD BJ—MS20470AD	SEE 0—70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS		CONTRACT NO.	OPTICAL COMPONENTS - DETECTOR OPTICAL SYSTEM
	ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED UL [ ] FOR USAGE LIST	MATL PROD. ENGR		SIZE C CODE IDENT 14170 DRAWING NO. 596-722-008 SCALE FULL SIZE RELEASED SHEET 1 OF 1 PACKAGE NO.

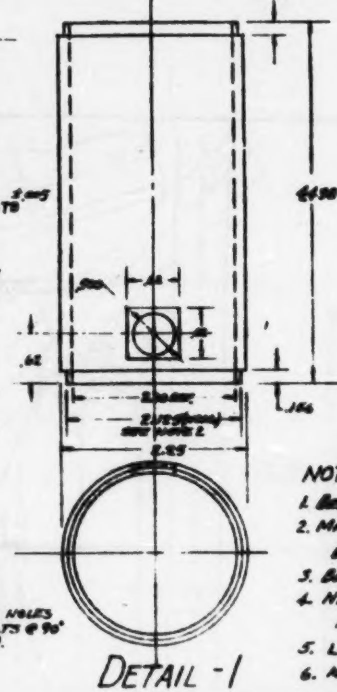
SECURITY CLASSIFICATION

REVISIONS

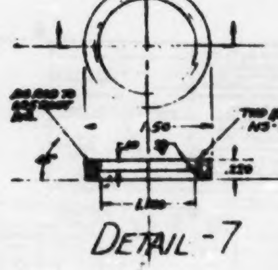
LTR	DESCRIPTION	DATE	APPROVED


-3
BRAZE EACH END OF -1: LINE UP CLEAR. HOLES IN -2 & -3; ORIENT CONN. HOLE AS SHOWN.
POLISH INSIDE SURFACE TO MIRROR FINISH AFTER BRAZING AND BEFORE PLATING.
4.875
-1
MS3134HY3-50P SOLDER TO -1
-2
-4
-5
-6
-7
596-722-008-5
CLEARANCE HOLES FOR 1/4 BOLTS @ 90° IN -3 (REF).
2.00 (REF)
45°
TAP DRILL .160 (#21) IN -2
TAP 10-32 NF2B IN -2
MS24693-C272
4 PLACES @ 90°

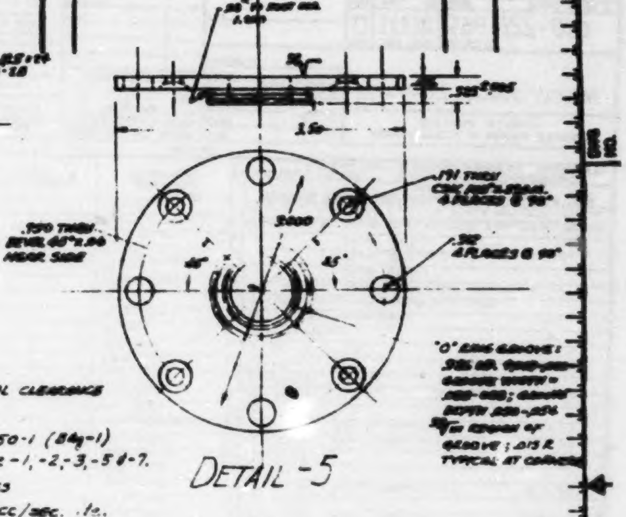
-60 ASSY.



DETAIL -1



DETAIL -7


3.50
3.000
45°
.191 THRU CSK 82° 4 PLACES @ 90°
.312 4 PLACES @ 90°
.550 THRU BEVEL 45° x .06 NEAR SIDE
"O" RING GROOVE:
TYPICAL AT CORNERS

DETAIL -5

NOTES:

1. BREAK ALL SHARP CORNERS.
2. MACHINE TO ALLOW -.003-.006 DIAMETRAL CLEARANCE BETWEEN -1 AND -2 & -3.
3. BRAZE ALLOY CONVAIR SPEC. 0-00350-1 (BAg-1)
4. NICKEL PLATE .0003-.0005 ALL OVER -1, -2, -3, -5 & -7. AFTER BUFFING OUTSIDE SURFACES
5. LEAK TEST -60 ASSY TO 10^{-9} STD CC/SEC. He.
6. MATING PLUG DEUTSCH DS07-35-059.

REQ PER ASSY / INSTL			-60	UNIT OF MEAS	ITEM OR FIND NO.	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	NOTE	(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT
			4				MS24693-C272	FLAT HEAD SCREW		10-32 x 0.5 CRES.
			1				MS3134HY3-50P	CONNECTOR		G.S. MARSHALL CO. 9674 E. TELSTAR AV. EL MONTE CALIF 91731
			1				596-722-008-5	WINDOW		
			1				-7	RING		0.5x4x4 BRASS PL. HALF HARD QQ-B-613 ALLOY 260
			1				-6	"O" RING		PARKER 2-021 VITON
			1				-5	END PLATE		.25 x2x2 BRASS PL. HALF HARD QQ-B 613 ALLOY 260
			1				-4	"O" RING		VEECO 1866-5 OR PARKER 2-227 VITON
			1				-3	PLAIN FLANGE		VEECO FLANGE SET BF-212 VEECO INST. CO. 575 N. MATHILDA
			1				-2	"O" RING FLANGE		SUNNYVALE CALIF. 94096.
			1				-1	TUBE		2.25 O.D. x .12 WALL [illegible] TUBE

NOTE SYMBOL: E—END ITEM G—GENERAL NOTE L—LIMIT M—MATERIAL R—REFERENCE DESIGNATION S—STOCK NO. U—USAGE DATA

PARTS LIST

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125 √
RIVET BASIC CODE-MS20
BB—MS20426AD
BJ—MS20470AD

SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70802 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
X ±.1 XX ±.03 XXX ±.010
ANGULAR PER 0-70802

ENTL.
PROD. ENGR

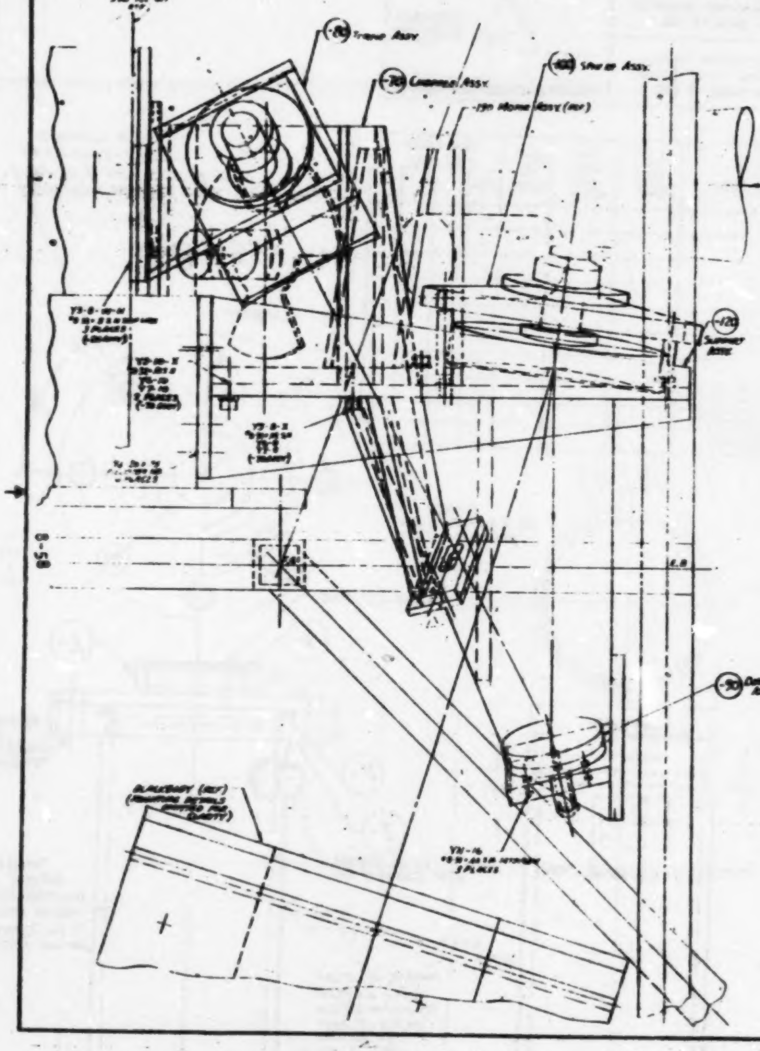
CHECK
STRESS
GR ENGR
DESIGN M. STEUFF 8/10/70
DRAWN
CONTRACT NO.

SECURITY CLASSIFICATION

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

DEWAR ASSEMBLY

SIZE C CODE IDENT 14170 DRAWING NO. 596-722-009
SCALE FULL RELEASED SHEET 1 OF 1
PACKAGE NO. DOC DISTR FORM



— CONTINUED ON SHEET 6 —

-130	-120	-110	-100	-90	-80	-70	-60	PART OR IDENTIFYING NUMBER	FIND NO.	NOMENCLATURE OR DESCRIPTION	ZONE	MATERIAL	SPECIFICATION
						1			-130	MOTOR ASSY			
							1		-120	SUPPORT ASSY			
							1		-110	PLATFORM MOUNT ASSY			
							1		-100	SPHERE ASSY			
							1		-90	DIAGONAL ASSY			
							1		-80	TOROID ASSY			
							1		-70	CHOPPER ASSY			
			1					596-722-001-1		SPHERICAL MIRROR			
				1				596-722-001-2		[illegible] MIRROR			
					1			596-722-001-3		TOROID MIRROR ([illegible])			
		1							-37	[illegible]		.12 x 3.0 x 2.5 x 10.0 ALUM ANGLE	
		2							-36	[illegible] SUPPORT SHAFT		[illegible]	
		1							-35	PLATFORM PLATE		.12 x 3.0 x 7.6 2024-T3 ALUM	
	3								-34	SPHERE SPRING		[illegible]	
				1					-33	DIAGONAL SPRING		[illegible]	
				3					-32	DIAGONAL CLIP		[illegible] ALUM PLATE	
2	2								-31	MOTOR MOUNT [illegible]		[illegible] EPOXY	—
1	1								-30	MOTOR MOUNT		[illegible] EPOXY	—
				1					-29	DIAGONAL STEM		2.0 DIA x 1.5 6061-T6 ALUM BAR	QQ-A-[illegible]
			3						-28	SPHERE STEM		[illegible] x 1.5 " "	"
			3						-27	PIN		MAKE FROM [illegible]	
	1								-26	FLAT POST		MAKE FROM [illegible]	
	1								-25	LONG POST		" " " "	
	1								-24	VEE POST		" " " "	
			1						-23	SPHERE MOUNT	6	.50 x 5.0 x 6.0 6061-T6 ALUM PLATE	QQ-A-[illegible]
					1				-22	COLLAR	6	[illegible] x 1.3 ALUM	
					1				-21	TOROID MOUNT	5	.31 x 7.6 x 4.6 6061-T6 ALUM PLATE	QQ-A-[illegible]
					1				-20	TOROID BASE	6	.31 x 7.0 x 3.6 "	"
	1								-19	DIAG BRACE	4	.50 x 4.3 x 7.9 [illegible] ALUM PLATE	QQ-A-[illegible]
	1								-18	DIAG PLATE	5	.25 x 2.9 x 3.4 "	"
	1								-17	DIAG SUPPORT	6	.25 x 2.1 x 8.6 "	"
	1								-16	DIAG MOUNT	6	.31 x 3.1 x 3.0 6061-T6 ALUM PLATE	QQ-A-[illegible]
	1								-15	LAMP SUPPORT BRACE	5	.25 x 1.1 x 6.3 [illegible] ALUM PLATE	QQ-A-[illegible]
	1								-14	LAMP SUPPORT	6	.25 x 2.2 x 4.0 "	"
	1								-13	LEFT BRACE	6	.25 x 1.9 x 9.3 "	"
	1								-12	RIGHT BRACE	6	.25 x 3.9 x 10.0 "	"
	1								-11	MOUNT PLATE	5	.25 x 3.3 x 10.3 "	"
	1								-10	PATH PLATE	6	.25 x 3.6 x 9.5 "	"
						4			-9	BUSHING		.25 DIA x [illegible] PHENOLIC	—
						2			-8	[illegible]		[illegible] FIBERGLASS BOARD	—
						4			-7	[illegible]		[illegible] x 1.0 x 6 [illegible]	"
									-6	HOUSING PLATE	6	MACH. FROM [illegible] ALUM	—
						1			-5	HOUSING [illegible]	6	" " " CY-[illegible]	"
						1			-4	HOUSING [illegible]	6	" " " CY-[illegible]	"
						1			-3	HOUSING [illegible]	6	" " " CY-[illegible]	"
						1			-2	[illegible]		MACH. FROM [illegible]	
						1			-1	[illegible]		MACH. FROM [illegible]	

PARTS LIST

UNLESS OTHERWISE SPECIFIED

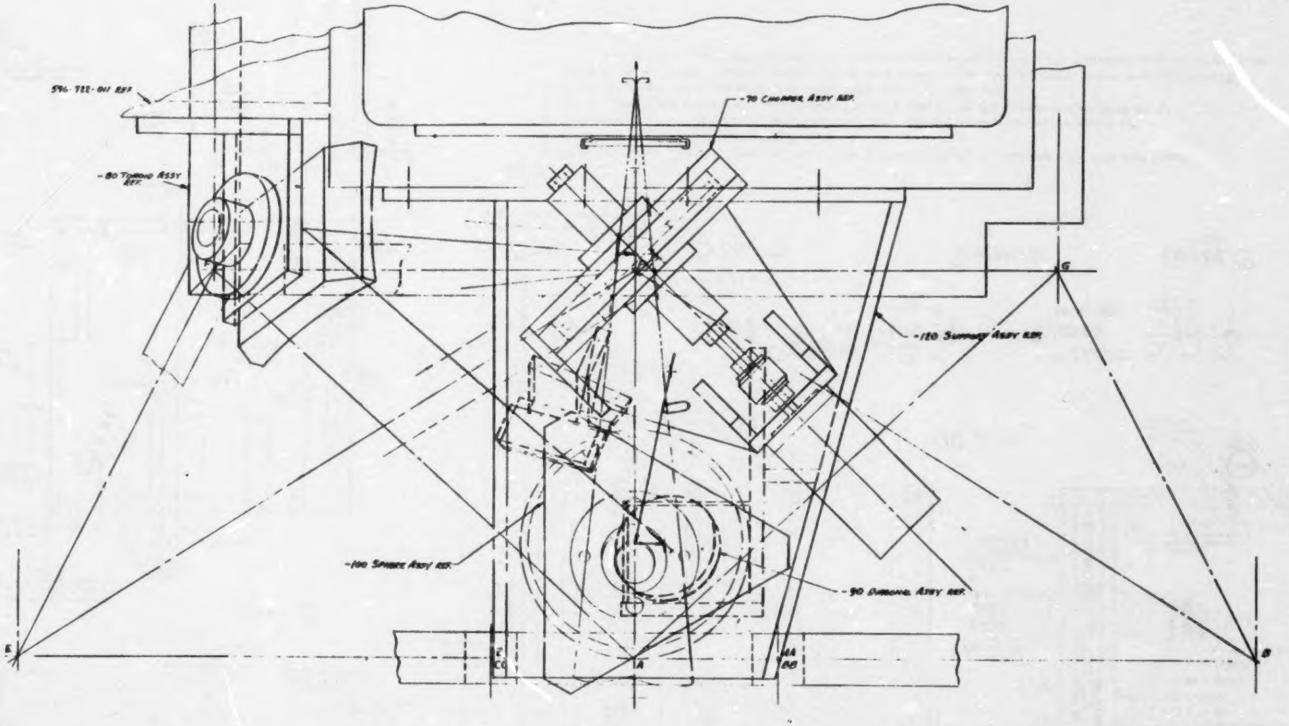
ALL MACHINED SURFACES 125√

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

REFERENCE OPTICAL SYSTEM

D 14170 596-722-010

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125 √
RIVET BASIC CODE-NAS523
BB—MS20426AD
BJ—MS20470AD

SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS
SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS
ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST

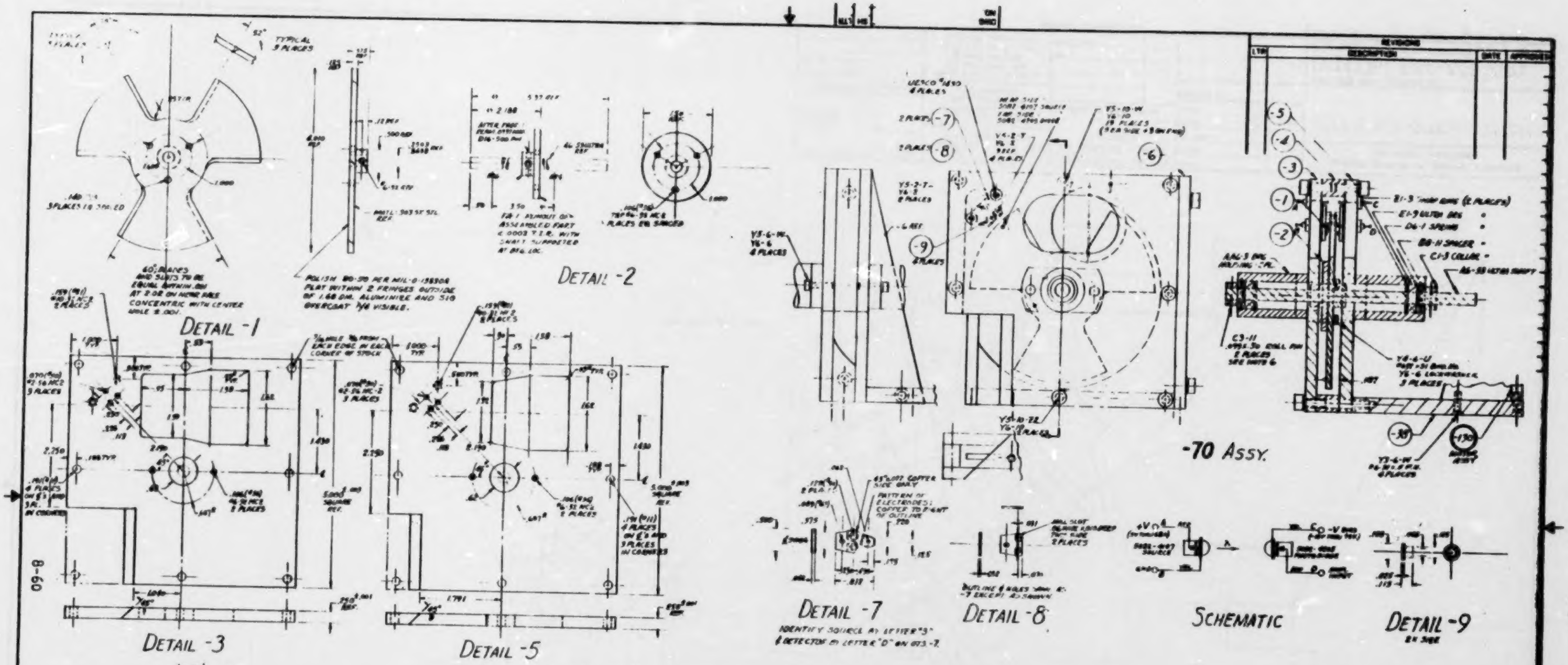
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ±.1 .XX ±.03 .XXX ±.010
ANGULAR PER 0-70902
MATL
PROD ENGR
SECURITY CLASSIFICATION

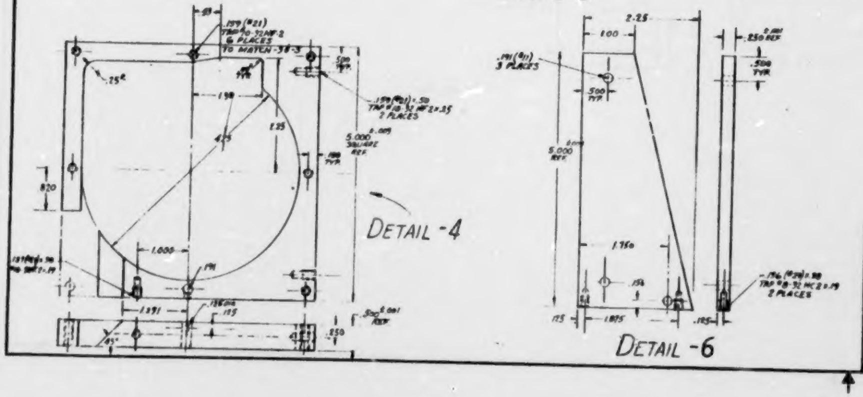
CHECK
STRESS
GR ENGR
DESIGN Ind 11/10/70
DRAWN
CONTRACT NO.

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

REFERENCE OPTICAL SYSTEM

SIZE D CODE IDENT 14170 DRAWING NO. 596-722-010
SCALE FULL RELEASED SHEET 2 OF 7
PACKAGE NO.


TYPICAL 3 PLACES
.140 DIA 3 PLACES EQ SPACED
60° 3 PLACES AND SLOTS TO BE EQUAL WITHIN .001 AT 2.02 ON HONE RAD CONCENTRIC WITH CENTER HOLE ±.001
POLISH 80-50 PER MIL-O-13830A FLAT WITHIN 2 FRINGES OUTSIDE OF 1.68 DIA. ALUMINIZE AND SIO OVERCOAT 1/4 VISIBLE.
MATL: 303 SS STL REF
DETAIL -1
FACE RUNOUT OF ASSEMBLED PART ≤ .0003 T.I.R. WITH SHAFT SUPPORTED AT BRG. LOC.
DETAIL -2
1/8 HOLE 1/4 FROM EACH EDGE IN EACH CORNER OF STOCK
DETAIL -3
DETAIL -5
UERCO #1690 4 PLACES
2 PLACES (-7)
2 PLACES (-8)
(-9) 4 PLACES
(-6)
YS-10-W Y6-10 18 PLACES
YS-10-22 Y6-10 2 PLACES
(-5)
(-4)
(-3)
(-1)
(-2)
B1-3 SNAP RING (2 PLACES)
E1-9 ULTRA BRG
D6-1 SPRING
B8-11 SPACER
C1-3 COLLAR
A6-53 ULTRA SHAFT
AA6-3 BRG HOUSING
C3-11 DOWEL PIN 2 PLACES SEE NOTE 6
Y8-4-U
Y6-6 LOCKWASHER 3 PLACES
(-38)
(-130)
-70 ASSY.
PATTERN OF ELECTRODES: COPPER TO RIGHT OF OUTLINE
DETAIL -7
IDENTIFY SOURCE BY LETTER "S" & DETECTOR BY LETTER "D" ON DTS -7.
DETAIL -8
SCHEMATIC
DETAIL -9
2X SIZE



NOTES:

1. BREAK ALL SHARP CORNERS .02 MAX × 45° EXCEPT FOR -1. COINED BREAK OF STOCK FOR -3, 4, 5 & 6 ACCEPTABLE.
2. BLACK ANODIZE -3, 4, 5, 6 AND AA6-3.
3. PRE-ASSEMBLE -2 ON A6-53 ULTRA SHAFT AND PIN; CHECK FACE RUNOUT AND CORRECT IF NECESSARY.
4. MOUNT -1 ON -2 AND CHECK STATIC AND DYNAMIC BALANCE (PERFORMED &/OR SUPERVISED BY DEPT 596-0)
5. FABRICATION AND INSTALLATION OF -7, 8 9 AND 5082 DIODES BY DEPT 596-0.
6. UPON FINAL ASSEMBLY CHECK CHOPPER BLADE FOR EQUALITY OF GAP BETWEEN -1 AND HOUSING (-3 AND -5)
   USE EXTREME CARE NOT TO MAR THE POLISHED CHOPPER FACE; (DEPT. 596-0 SUPERVISION); PIN C1-3 COLLARS.

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125√
RIVET BASIC CODE NAS523
BB—MS20426AD
BJ—MS20470AD

SEE 0—70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS
SEE 0—70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS
ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST

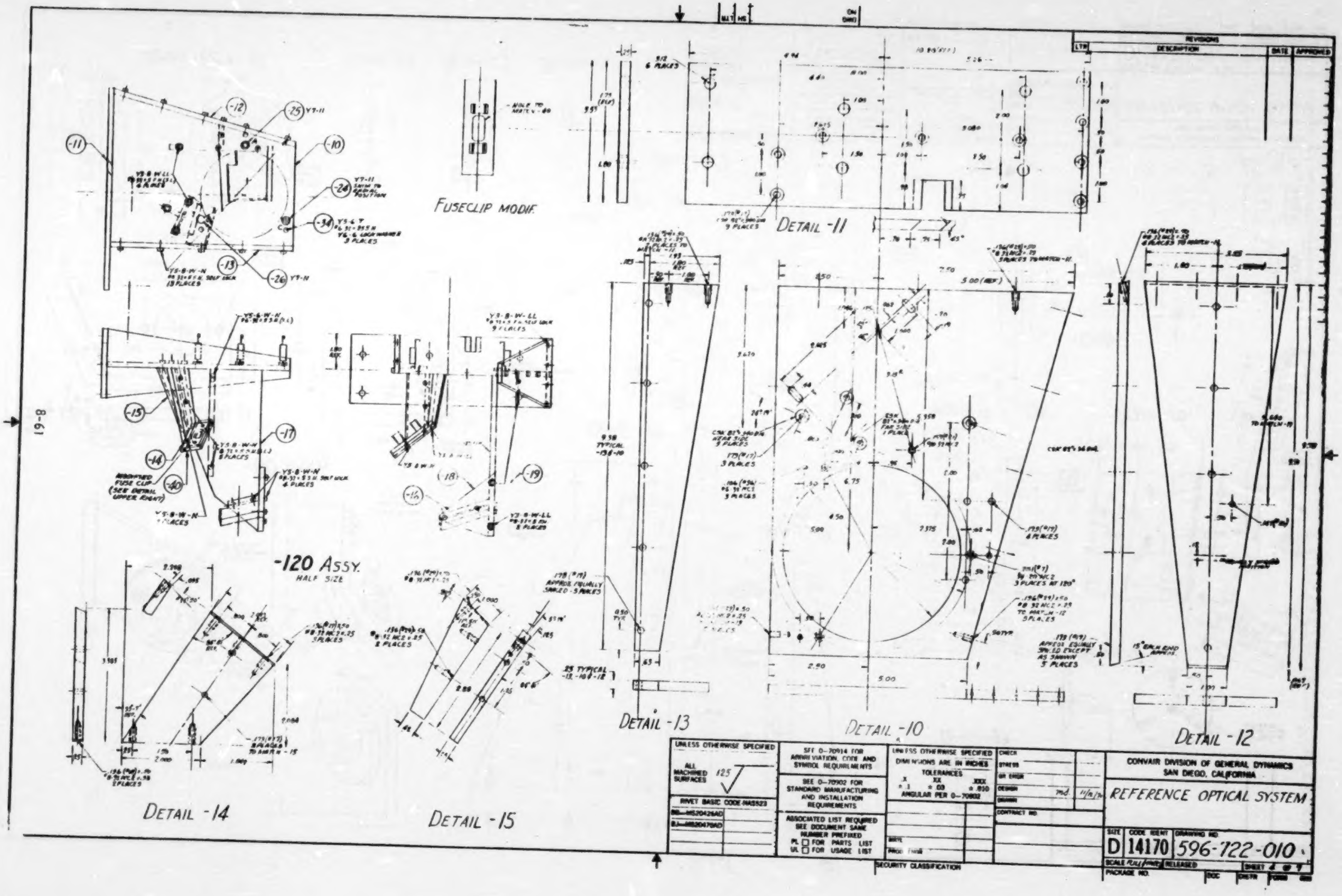
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
X ±.1 XX ±.03 XXX ±.010
ANGULAR PER 0—70902
MATL
PROD ENGR
SECURITY CLASSIFICATION

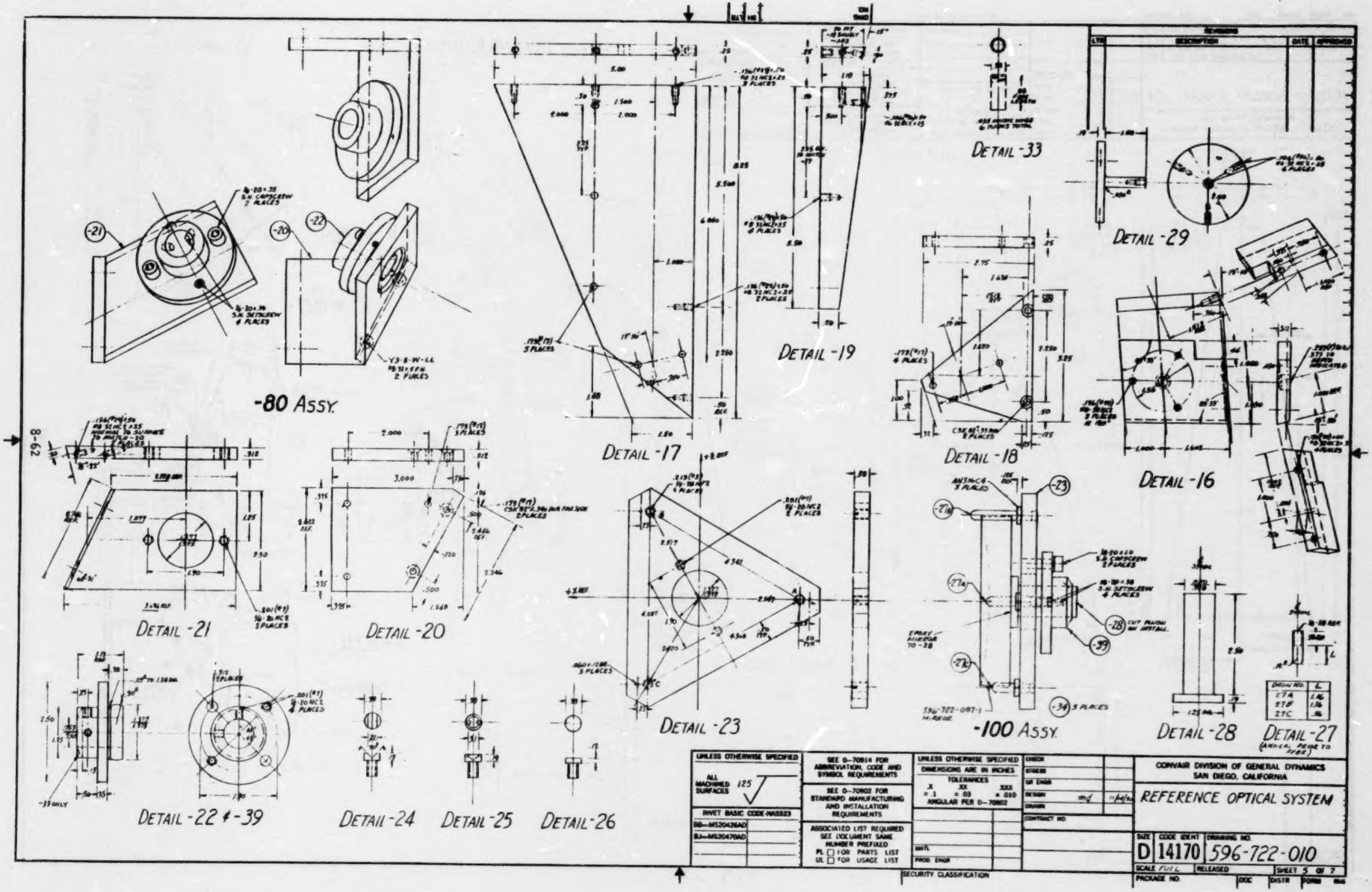
CHECK
STRESS
GR ENGR
DESIGN 10/8/70
DRAWN
CONTRACT NO

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

REFERENCE OPTICAL SYSTEM

SIZE D
CODE IDENT 14170
DRAWING NO. 596-722-010
SCALE
RELEASED
SHEET
PACKAGE NO.


-120 ASSY.
HALF SIZE
FUSECLIP MODIF.
DETAIL -11
DETAIL -13
DETAIL -10
DETAIL -12
DETAIL -14
DETAIL -15
MODIFIED FUSE CLIP (SEE DETAIL UPPER RIGHT)
REVISIONS
LTR
DESCRIPTION
DATE
APPROVED
UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125
RIVET BASIC CODE NAS523
SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS
SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS
ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
.X ±.1
.XX ±.03
.XXX ±.010
ANGULAR PER 0-70902
SECURITY CLASSIFICATION
CHECK
STRESS
GR ENGR
DESIGN
DRAWN
CONTRACT NO
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA
REFERENCE OPTICAL SYSTEM
SIZE D
CODE IDENT 14170
DRAWING NO 596-722-010
SCALE
RELEASED
SHEET
PACKAGE NO.



UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125 √
RIVET BASIC CODE-NAS523
BB—MS20426AD
BJ—MS20470AD

SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS
SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS
ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
X ±.1 XX ±.03 XXX ±.010
ANGULAR PER 0-70902
MAT'L
PROD. ENGR
SECURITY CLASSIFICATION

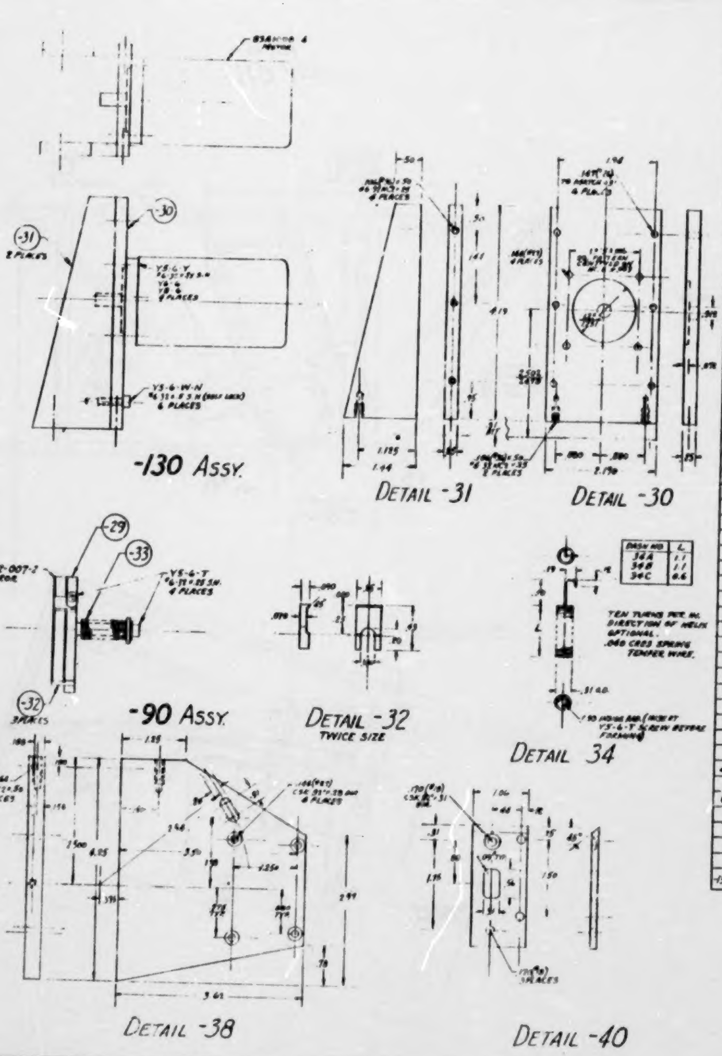
CHECK
STRESS
GP ENGR
DESIGN
DRAWN
CONTRACT NO

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

REFERENCE OPTICAL SYSTEM

SIZE	CODE IDENT	DRAWING NO.
D	14170	596-722-010

SCALE FULL
RELEASED
SHEET 5 OF 7
PACKAGE NO.
DOC
DISTR
FORM


-130 ASSY.
(30)
(31) 2 PLACES
Y5-6-Y #6-32 x .70 S.H. Y8-6 8 PLACES
Y5-6-W-N #6-32 x .50 S.H. (SELF LOCK) 6 PLACES
DETAIL -31
DETAIL -30
-90 ASSY.
(29)
(33)
(32) 3 PLACES
596-722-007-2 MIRROR
Y5-6-T #6-32 x .25 S.H. 4 PLACES
DETAIL -32
TWICE SIZE
DETAIL 34
DASH NO | L
34A | 1.1
34B | 1.1
34C | 0.6
TEN TURNS PER IN. DIRECTION OF HELIX OPTIONAL. .040 CRES SPRING TEMPER WIRE.
DETAIL -38
DETAIL -40

-130	-120	-110	-100	-90	-80	-70	-60	UNIT OF MEAS	ITEM OR FIND NO	CODE IDENT NO	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	NOTE TEXT (STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT)
REQ PER ASSY / INSTL													
		2									SCREW	#[illegible] 32 x [illegible] PAN HD	
		2									MS3[illegible] NUT	#6	CRES S.S.
		2									SCREW	#6-32 x [illegible]	CRES S.S.
		6									Y8-10 NUT	#10	
		4									SCREW	#10-32 x [illegible] FH	·
		2									SCREW	#10-32 x .19 RH	·
		1									SCREW	#8-32 x .19 FH	·
		8									Y8-8 NUT	#8	·
		7									SCREW	#8-32 x .19 RH	·
4											Y8-6 NUT	#6	CRES S.S.
4											Y5-6-Y CAPSCREW	#6-32 x .70 S.H.	CRES S.S.
	1	1									LITTLEFUSE 358	FUSE CLIP	
		1									EOI WS135R	BLACKBODY	ELECTRO-OPTICAL INDUSTRIES SANTA BARBARA, CALIF
		1									ORIEL C-13-61	Hg-A LAMP	(WITH C-13-00 20 SHIELD) ORIEL OPTICS CORP, STAMFORD CONN.
		1									ORIEL C-73-16	TRANSFORMER	· · · · ·
		8					1				Y6-8 LOCKWASHER	#8	
		4									-41	SPACER	.50 x .9 2024-T3 ALUM ROD
	1										-40	LAMP [illegible] PLATE	.12 x 1.1 x 2.4 2024-T3 ALUM.
			1								-33	[illegible] COLLAR	2.50 DIA x 1.9 ALUM
						1					-29	SWIVEL PLATE	.31 x 5 x 4 6061-T6 ALUM
							1				Y7-8 WASHER	#8	CRES S.S.
							2				Y5-10X CAPSCREW	#10-32 x .62 S.H.	CRES S.S.
			3								AN316-[illegible] NUT	¼-28 NF2 ([illegible])	CRES S.S.
						2					Y5-[illegible]-22 CAPSCREW	#10-32 x 1.5 S.H.	CRES S.S.
							2				Y7-10 WASHER	#10	
1											GLOBE 38A1008-4 MOTOR	6000 RPM 400HZ 115V [illegible]	[illegible] HYSTERESIS SYNCH. [illegible]
	3										[illegible] WASHER	¼"	CRES. S.S.
	3			4							Y5-6-T CAPSCREW	#6-32 x .25 S.H.	· ·
	16				2						Y3-8-W-LL SCREW	#8-32 x .50 F.H. SELF LOCK	· ·
			4		6						SETSCREW	¼-20 x .38 S.H.	
			2		2						CAPSCREW	¼-20 x .75 S.H.	
						1					AG-53 ULTRA SHAFT	.250 x 5.37 LONG	.2498 [illegible] CRES S.S.
						2					21-3 SNAP RING	.25 SHAFT	·
						2					[illegible] ULTRA BEARING	.250 BORE DBL SHIELD	.2498 [illegible] BORE · .625 O.D.
						2					Do. CURVED WASHER	.265 I.D. ; .367 O.D.	·
						2					BB-11 SPACER	¼" SHAFT [illegible] LONG	·
						2					C1-3 COLLAR	¼" SHAFT	·
						2					AA6-3 BRG HOUSING	.625 BORE 1¼ LONG	ALUM
						3					Y4-6-U SCREW	#6-32 x .31 BINDING HD	CRES. S.S.
						2					C5-11 ROLL PIN	.093 DIA x .50	·
						4					Y3-6-W SCREW	#6-32 x .50 F.H.	
		6				15	[illegible]				Y6-10 LOCKWASHER	#10	·
						13					Y5-10-W CAPSCREW	#10-32 x .50 S.H.	·
						1					HP-5082-4205 DETECTOR		
						1					HP 5082-4107 SOURCE		
						4					UESCO #M30 TERMINAL	FEEDTHROUGH	
						[illegible]					Y6-2 LOCKWASHER	#2	CRES S.S.
						6					Y5-2-T CAPSCREW	#2-56 x .25 S.H.	
4	3					[illegible]					Y6-6 LOCKWASHER	#6	
	3					4					Y5-6-W CAPSCREW	#6-32 x .50 S.H.	
6	1										Y5-6-W-N CAPSCREW	#6-32 x .50 S.H. SELF LOCK	
							3				Y11-16 SETSCREW	#8-32 x .62 S.H.	
							1				Y5-8-X CAPSCREW	#8-32 x .62 S.H.	
	25						6				Y5-8-W-N CAPSCREW	#8-32 x .50 S.H. SELF LOCK	
											SCREW	¼-20 x [illegible] FILLISTER HD	CRES. S.S.

NOTE SYMBOL: E—END ITEM L—LIMIT R—REFERENCE DESIGNATION
G—GENERAL NOTE M—MATERIAL S—STOCK NO. U—USAGE DATA

PARTS LIST

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125 √
RIVET BASIC CODE-NAS523
BB—MS20426AD
BJ—MS20470AD

SEE 0—70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0—70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED UL ☐ FOR USAGE LIST

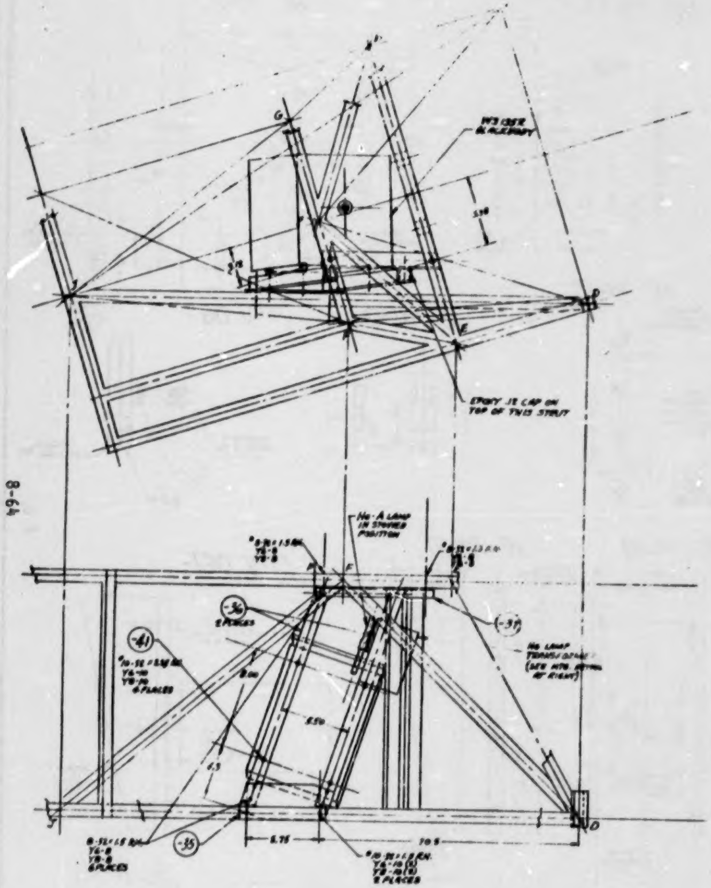
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
X ±.1 XX ±.03 XXX ±.010
ANGULAR PER 0—70902

CHECK
STRESS
GR ENGR
DESIGN TKM [illegible]
DRAWN
CONTRACT NO.
MATL
PROJ ENGR
SECURITY CLASSIFICATION

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

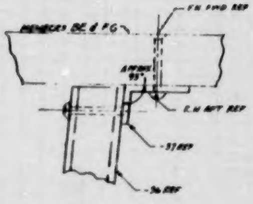
REFERENCE OPTICAL SYSTEM

SIZE D
CODE IDENT 14170
DRAWING NO. 596-722-010
SCALE FULL [illegible]
RELEASED
SHEET 6 OF 7
PACKAGE NO.

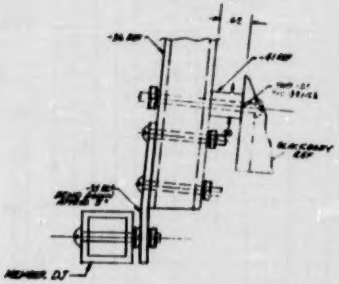


G
J
D
E
MS 1251E BLACKBODY
3.10
EPOXY .12 CAP ON TOP OF THIS STRUT
He-A LAMP IN STOWED POSITION
F
-36 2 PLACES
-41
10-32 x .5 RH YS-10 YB-10 6 PLACES
-37
He LAMP TRANSFORMER (SEE MTG. DETAIL AT RIGHT)
8.50
6.5
8-32 x 1.5 RH YS-8 YB-8 6 PLACES
-35
5.75
70.5
10-32 x 1.5 RH YS-10 (2) YB-10 (2) 2 PLACES

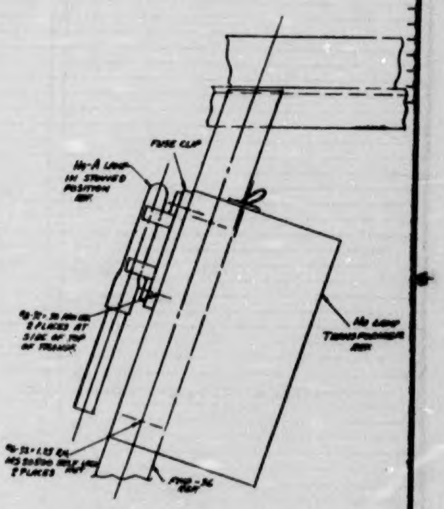
-110 ASSY
1/4 SIZE



TOP MOUNTING DETAIL
FULL SIZE



BOTTOM MOUNTING DETAIL
FULL SIZE



TRANSFORMER MOUNTING DETAIL
FULL SIZE

REVISIONS
LTR | DESCRIPTION | DATE | APPROVED

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125√
RIVET BASIC CODE-NAS523
BB-MS20426AD
BJ-MS20470AD

SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS
SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS
ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ± .1 .XX ± .03 .XXX ± .010
ANGULAR PER 0-70902
MATL
PROD. ENGR
SECURITY CLASSIFICATION

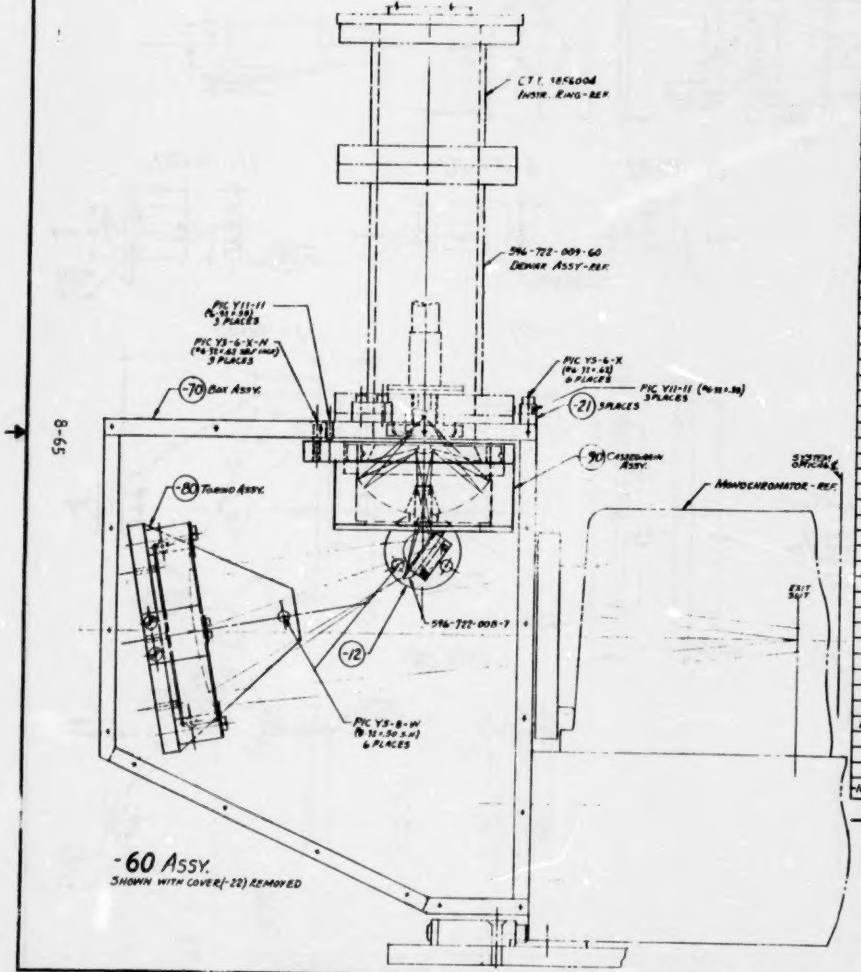
CHECK
STRESS
GR ENGR
DESIGN md 1/10/..
DRAWN
CONTRACT NO.

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

REFERENCE OPTICAL SYSTEM

SIZE D CODE IDENT 14170 DRAWING NO. 596-722-010
SCALE NOTED RELEASED SHEET 7 OF 7
PACKAGE NO.

NOTES:
1. UNLESS OTHERWISE INDICATED BREAK ALL SHARP CORNERS .02 × 45°.
2. BLACK ANODIZE ALL ALUM. PARTS.
3. EPOXY: EPON 828 AND VERSAMID 125 OR EQUIV.



-60 ASSY.
SHOWN WITH COVER (-22) REMOVED

-100	-90	-80	-70	-60	UNIT OF MEAS	ITEM OR FIND NO.	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION		(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT	
	3								#4-40×.25 F.H. SCREW			
	3							PIC Y3-6-V	#6-32×.38 F.H SCREW		CRES ST. STL.	
		3						〃 Y5-6-V-H	#6-32×.38 S.H CAPSCREW		〃	
		2						〃 Y3-8-Y	#8-32×.62 S.H CAPSCREW		〃	
		3						〃 Y3-6-X	#6-32×.62 F.H SCREW		〃	
		6						〃 Y5-2-T	#2-56×.25 S.H CAPSCREW		〃	
			50					〃 Y5-6-11	#6-32×.91 S.H CAPSCREW		〃	
				6				〃 Y5-8-H	#8-32×.53 S.H CAPSCREW		〃	
				3				〃 Y3-6-X-U	#6-32×.62 F.H SCREW (SELF LOCK)		〃	
				6				〃 Y5-6-X	#6-32×.62 S.H. CAPSCREW		〃	
				6				〃 Y11-11	#6-32×.38 SETSCREW		〃	
	1							-100	CASS. SEC. SUBASSY			
	3							-24	SPRING		.015 DIA × LENGTH REQ'D MUSIC WIRE	
	4							-23	ADJ. SCREW		MAKE FROM PIC Y11-11	
			1					-22	BOX COVER		.31×9.7×8.6 6061-T6 ALUM.	QQ-A-327
				3				-21	ADJ. BLOCK		.31×.5×1.0 〃 〃	〃
	1							-20	CASS. FIELD LENS MT. NUT		.08×.61×1.1 2024-T3 ALUM.	QQ-A-250/4
	1							-19	〃 〃 〃 MOUNT		.75 DIA×1.5 2024-T6 ALUM. ROD	QQ-A-225/6
1								-18	〃 SEC. PLUG		.06×.3×.3 2024-T6 ALUM. ROD	QQ-A-225/6
4								-17	〃 SEC. VANE		.031×.6×1.1 2024-T3 ALUM.	QQ-A-250/4
1								-16	〃 SEC. RING		.31×2.6×2.6 6061-T6 ALUM.	QQ-A-316
	1							-15	〃 ADJ. RING		.31×3.2×3.2 〃 〃	〃
	1							-14	〃 PRI. FLANGE		.12×3.6×3.6 〃 〃	〃
	1							-13	〃 MOUNT		4.2×3.6×1.7 〃 〃	QQ-A-200/9
				1				-12	DIAGONAL MOUNT		MAKE FROM PERKIN-ELMER 012-0037	
		1						-11	TOROID MOUNT TOP		.25×1.1×1.3 6061-T6 ALUM.	QQ-A-327
		3						-10	TOROID MOUNT SPRING		.020×.61×.7 SPRING TEMPER STAINLESS STEEL	—
		2						-9	TOROID MOUNT POST		.50 DIA×1.3 2024-T6 ALUM ROD	QQ-A-225/6
		1						-8	TOROID MOUNT BOTTOM		.31×4.6×3.1 6061-T6 ALUM.	QQ-A-327
		1						-7	TOROID MOUNT PLATE		.31×4.6×4.0 〃	〃
			1					-6	BOX TOP		.31×8.6×4.6 〃	〃
			1					-5	BOX BACK		.31×6.5×4.6 〃	〃
			1					-4	BOX BOT. BACK		.31×7.0×4.6 〃	〃
			1					-3	BOX BOT. FRONT		.31×2.2×4.6 〃	〃
			1					-2	BOX FRONT		.31×9.1×4.6 〃	〃
			1					-1	BOX SIDE		.31×9.7×8.6 〃	〃
				1				-90	CASSEGRAIN ASSY.			
				1				-80	TOROID ASSY			
				1				-70	BOX ASSY.			
	1							596-722-008-4	PRI. MIRROR			
1								-3	SEC. MIRROR			
	1							-2	DET. FIELD LENS		IRTRAN-2 (REF.)	
				1				-7	DIAGONAL MIRROR			
		1						596-772-008-1	TOROIDAL MIRROR			

REQ PER ASSY / INSTL

NOTE SYMBOL: E—END ITEM G—GENERAL NOTE L—LIST M—MATERIAL R—REFERENCE DESIGNATOR S—STOCK NO. U—USAGE DATA

PARTS LIST

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125 √

RIVET BASIC CODE-NAS523
BB—MS20426AD
BJ—MS20470AD

SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ±.1 .XX ±.03 .XXX ±.010
ANGULAR PER 0-70902

MATL.
PROD. ENGR.

CHECK
STRESS
GR. ENGR.
DESIGN M. STREIFF 9/15/70
DRAWN
CONTRACT NO.

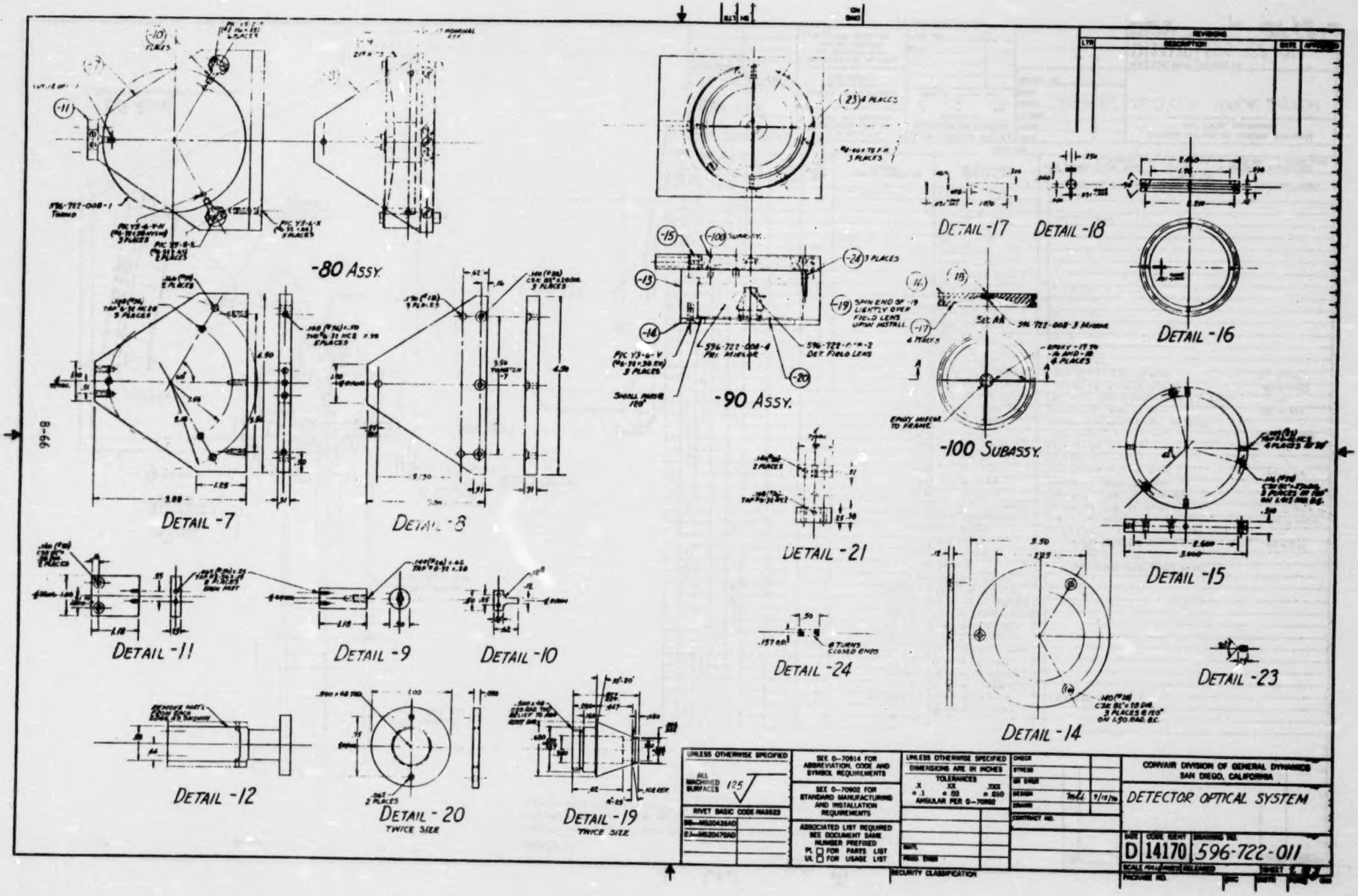
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

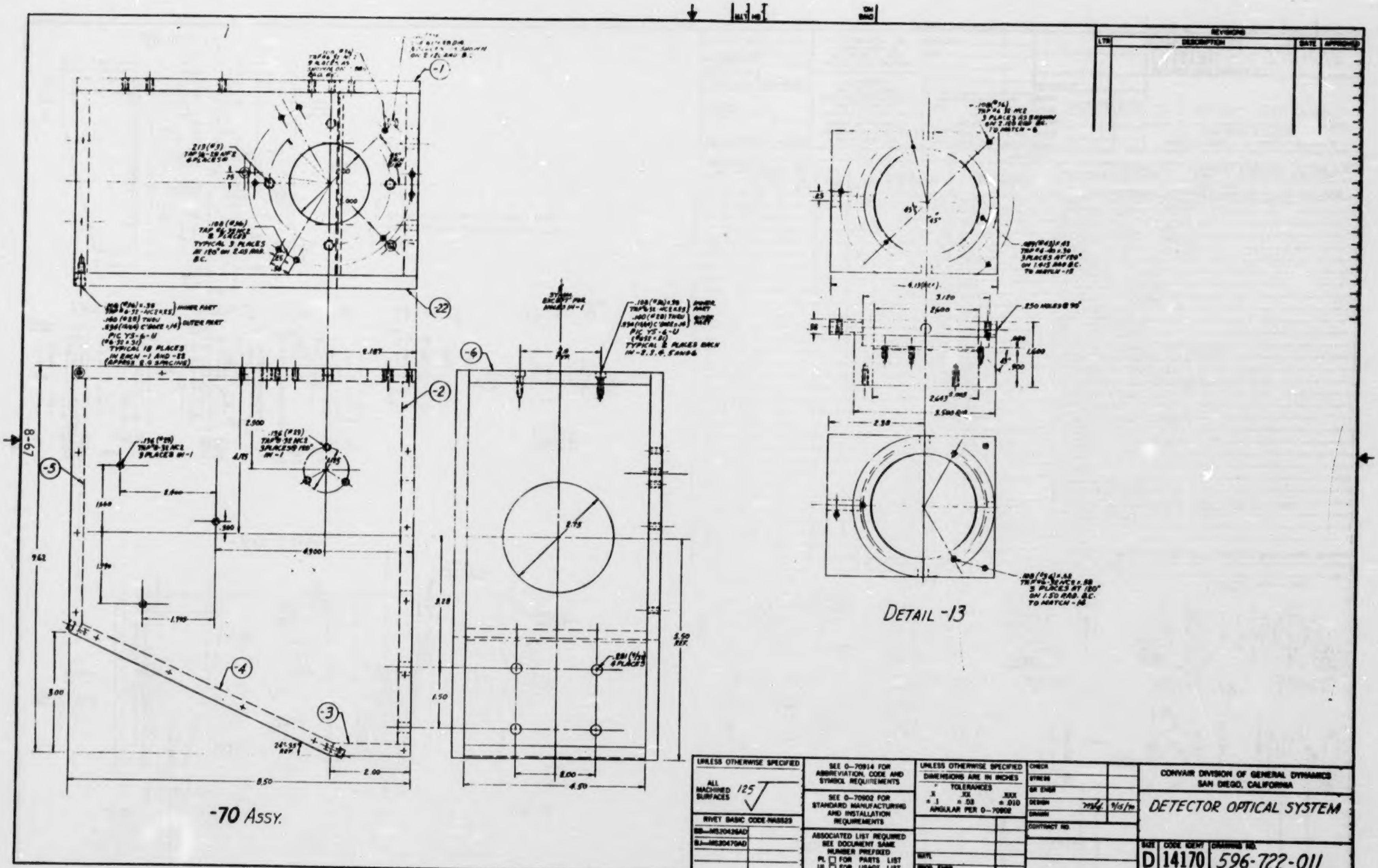
DETECTOR OPTICAL SYSTEM

SIZE D
CODE IDENT 14170
DRAWING NO. 596-722-011

SCALE FULL
RELEASED
SHEET
PACKAGE NO.

SECURITY CLASSIFICATION


-80 Assy.
-90 Assy.
-100 Subassy.
Detail -7
Detail -8
Detail -9
Detail -10
Detail -11
Detail -12
Detail -14
Detail -15
Detail -16
Detail -17
Detail -18
Detail -19
Twice size
Detail -20
Twice size
Detail -21
Detail -23
Detail -24
(23) 4 places
(24) 3 places
(-19) Spin end of -19 lightly over field lens upon install.
596-722-008-4 Pri. mirror
596-722-008-2 Det. field lens
596-722-008-3 Mirror
Sec. AA
Epoxy mirror to frame
8 turns closed ends
Revisions
Ltr
Description
Date
Approved
Unless otherwise specified
All machined surfaces 125
Rivet basic code-NAS523
See 0-70914 for abbreviation, code and symbol requirements
See 0-70902 for standard manufacturing and installation requirements
Associated list required see document same number prefixed
PL ☐ for parts list
UL ☐ for usage list
Unless otherwise specified dimensions are in inches
Tolerances
.X ±.1
.XX ±.03
.XXX ±.010
Angular per 0-70902
Check
Stress
Design
Drawn
Contract no.
Security classification
Convair Division of General Dynamics
San Diego, California
Detector Optical System
Size D
Code ident 14170
Drawing no. 596-722-011
Scale
Released
Sheet
Package no.



UNLESS OTHERWISE SPECIFIED

ALL MACHINED SURFACES 125 √

RIVET BASIC CODE-NAS523

BB—MS20426AD

BJ—MS20470AD

SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED

PL ☐ FOR PARTS LIST

UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED

DIMENSIONS ARE IN INCHES

TOLERANCES

.X ±.1 .XX ±.03 .XXX ±.010

ANGULAR PER 0-70902

MATL

PROD ENGR

SECURITY CLASSIFICATION

CHECK

STRESS

GR ENGR

DESIGN 9/15/70

DRAWN

CONTRACT NO.

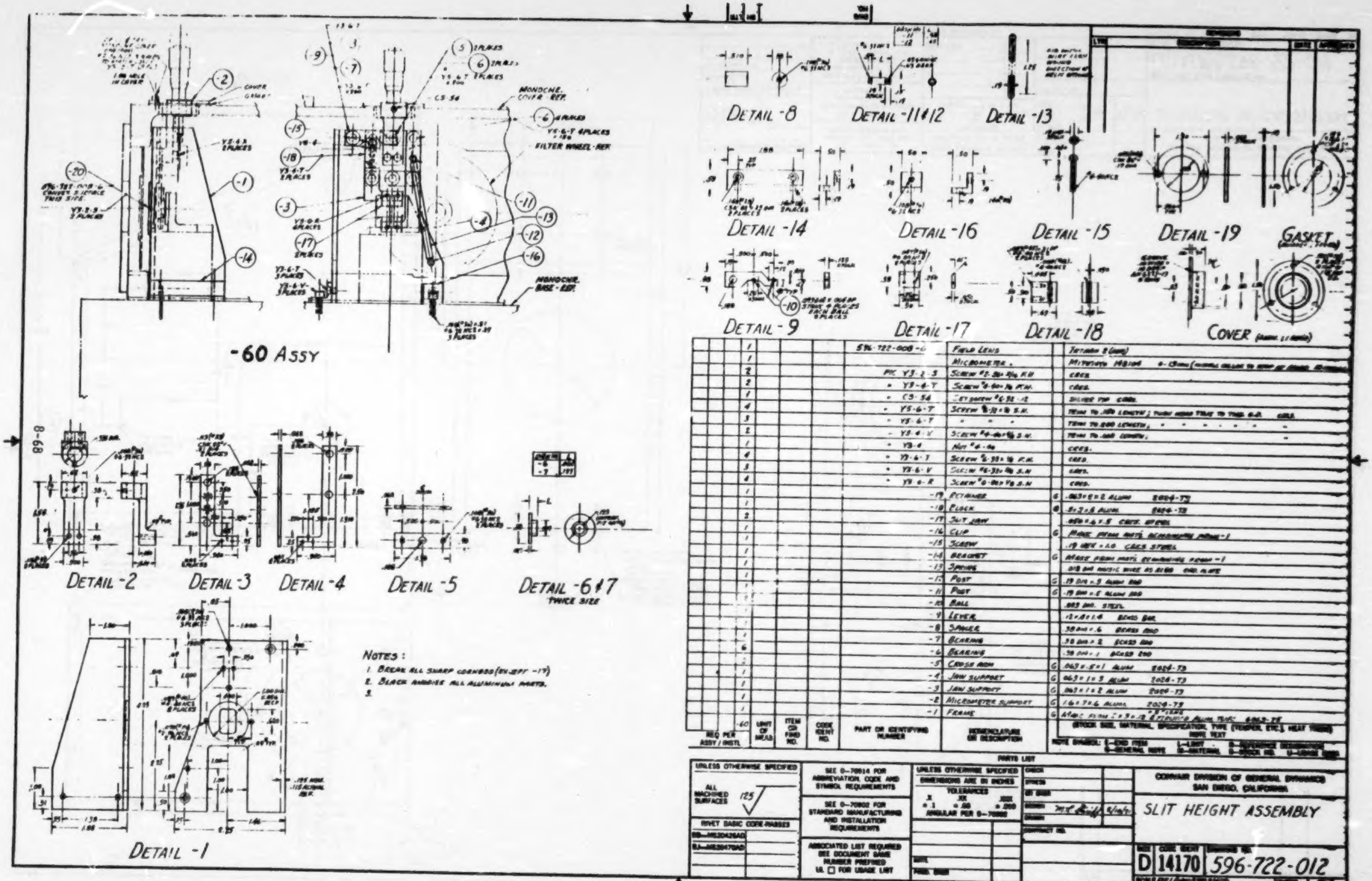
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

DETECTOR OPTICAL SYSTEM

SIZE	CODE IDENT	DRAWING NO.
D	14170	596-722-011

SCALE FULL RELEASED SHEET 2 OF 2

PACKAGE NO.



NOTES:
1. BREAK ALL SHARP CORNERS (EXCEPT -17)
2. BLACK ANODIZE ALL ALUMINUM PARTS.
3.

REQ PER ASSY / INSTL -60	UNIT OF MEAS	ITEM OR FIND NO.	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION		(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT
1				596-722-008-6	FIELD LENS		Tetman 8 (mm)
1					MICROMETER		MITUTOYO 148106 0-13mm ([illegible])
2				PK Y3-2-3	SCREW #2-56×3/16 F.H.		CRES.
2				" Y3-4-T	SCREW #4-40×1/4 F.H.		CRES.
1				" CS-54	SETSCREW #6-32-12		SILVER TIP CRES.
4				" Y5-6-T	SCREW #6-32×1/4 S.H.		TRIM TO .150 LENGTH; TURN HEAD TRUE TO THD. O.D. CRES.
3				" Y5-6-T	" " "		TRIM TO .200 LENGTH, " " " " " " "
2				" Y3-4-V	SCREW #4-40×3/8 S.H.		TRIM TO .40 LENGTH, "
1				" Y3-4	NUT #4-40		CRES.
4				" Y3-6-T	SCREW #6-32×1/4 F.H.		CRES.
3				" Y3-6-V	SCREW #6-32×3/8 S.H.		CRES.
4				" Y3-0-R	SCREW #0-80×1/8 S.H.		CRES.
1				-19	RETAINER	G	.063×2×2 ALUM 2024-T3
1				-18	BLOCK	G	.5×2×5 ALUM 2024-T3
2				-17	SLIT JAW		.050×.4×.5 CRES. STEEL
1				-16	CLIP	G	MAKE FROM MAT'L REMAINING FROM -1
1				-15	SCREW		.19 HEX ×1.0 CRES STEEL
1				-14	BRACKET	G	MAKE FROM MAT'L REMAINING FROM -1
1				-13	SPRING		.018 DIA MUSIC WIRE AS REQD [illegible]
1				-12	POST	G	.19 DIA ×.3 ALUM ROD
1				-11	POST	G	.19 DIA ×.5 ALUM ROD
[illegible]				-10	BALL		.083 DIA. STEEL
1				-9	LEVER		.12×.8×1.4 BRASS BAR
1				-8	SPACER		.38 DIA ×.6 BRASS ROD
1				-7	BEARING		.38 DIA ×2 BRASS ROD
6				-6	BEARING		.38 DIA ×.1 BRASS ROD
[illegible]				-5	CROSS ARM	G	.063×.5×1 ALUM 2024-T3
1				-4	JAW SUPPORT	G	.063×1×3 ALUM 2024-T3
1				-3	JAW SUPPORT	G	.063×1×2 ALUM 2024-T3
1				-2	MICROMETER SUPPORT	G	1.6×7×6 ALUM 2024-T3
1				-1	FRAME	G	MACH FROM [illegible]×3×12 EXTRUDED ALUM TUBE 6063-T6

NOTE SYMBOL: E—END ITEM L—LIMIT R—REFERENCE DESIGNATION G—GENERAL NOTE M—MATERIAL S—STOCK NO. U—USAGE [illegible]

PARTS LIST

UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES 125√

RIVET BASIC CODE-MASSES
BB—MS20426AD
BJ—MS20470AD

SEE 0-70014 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70002 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT BASE NUMBER PREFIXED UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
.X ±.1 .XX ±.03 .XXX ±.010
ANGULAR PER 0-70002

CHECK
STRESS
GP ENGR
DESIGN
DRAWN
CONTRACT NO.

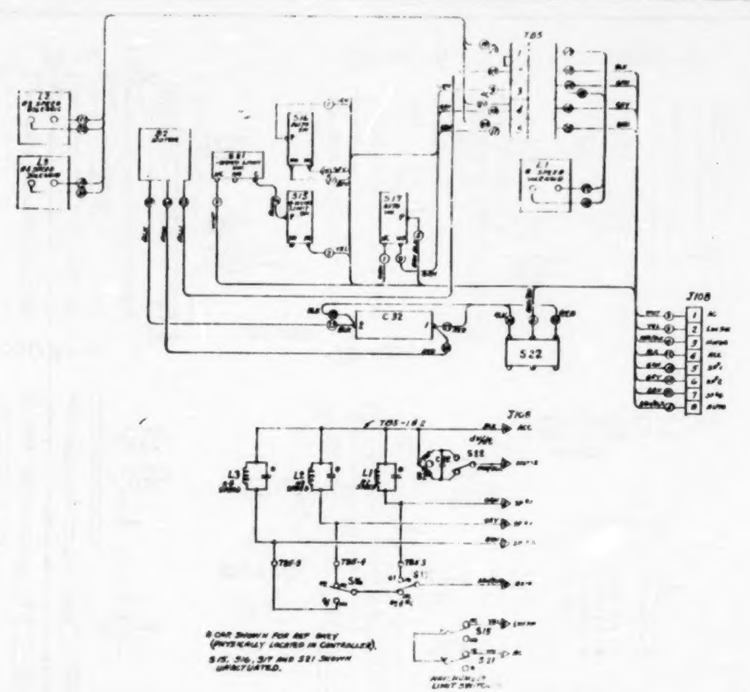
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

SLIT HEIGHT ASSEMBLY

SIZE D CODE IDENT 14170 DRAWING NO. 596-722-012

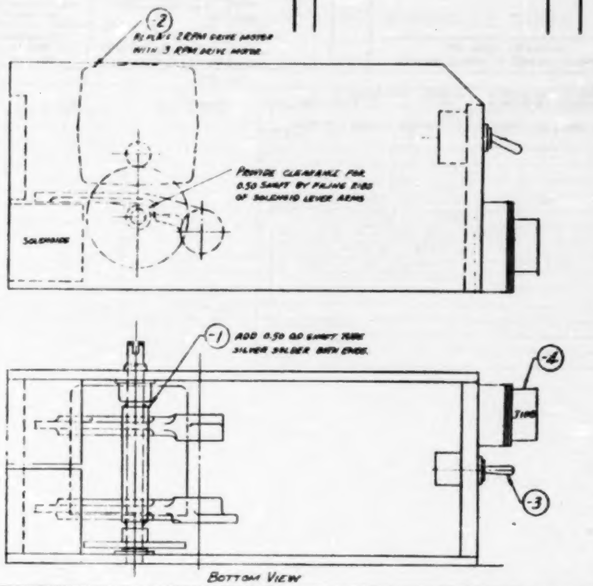
SCALE FULL/NOTED RELEASED SHEET 1 OF 1
PACKAGE NO.

SECURITY CLASSIFICATION



8 CAR SHOWN FOR REF ONLY (PHYSICALLY LOCATED IN CONTROLLER).

S15, S16, S17 AND S21 SHOWN UNACTUATED.


-2
REPLACE 2RPM DRIVE MOTOR WITH 3 RPM DRIVE MOTOR
PROVIDE CLEARANCE FOR 0.50 SHAFT BY FILING RIBS OF SOLENOID LEVER ARMS
SOLENOID
-1
ADD 0.50 OD SHAFT TUBE SILVER SOLDER BOTH ENDS.
-4
J108
-3
BOTTOM VIEW

NOTES:

1. THIS WAVENUMBER DRIVE IS IDENTICAL TO PERKIN ELMER 012-0109 EXCEPT FOR THE FOLLOWING MODIFICATIONS:
2. REPLACE 2RPM MOTOR WITH SIMILAR 3 RPM MOTOR (-2); (TO GIVE DESIRED SPEED).
3. ADD SHAFT TUBE (-1) AS SHOWN AND PROVIDE CLEARANCE IN SOLENOID LEVER ARMS; (TO STIFFEN SHAFT).
4. REMOVE W.L. MARKER SWITCHES S7 & S8, WIRING AND PLUG PM10 (REF. P.E SCHEMATIC 012-0312); NOT USED.
5. CHANGE PLUG PM14 FROM CANNON TYPE CONNECTOR TO AMPHENOL CONNECTOR (J108).
6. ADD S22 (-3) TO PROVIDE THE WAVENUMBER DRIVE IN EITHER DIRECTION; USE MTG. HOLE VACATED BY S7.
7. REVERSE S15 TO PROVIDE MORE RANGE BETWEEN LIMITS.
8. ABOVE SCHEMATIC AND HARNESS DIAGRAM SIMILAR TO 012-0312 EXCEPT MODIFICATIONS ARE INCLUDED.

REQ PER ASSY / INSTL	UNIT OF MEAS	ITEM OR FIND NO	CODE IDENT NO	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT
1				012-0109	W.L. DRIVE	PERKIN ELMER
				-4	CONNECTOR	AMPHENOL
1				-3	SWITCH	DPDT MS35059-23
1				-2	MOTOR	BODINE KYC-22T5A1 (765UB016) 115V 3RPM 88IN.OZ. 85µfd
1				-1	SHAFT TUBE	0.50 OD × 0.312 I.D. × 2.25 304 ST STL.
60						

NOTE SYMBOL: E—END ITEM G—GENERAL NOTE L—LIMIT M—MATERIAL R—REFERENCE DESIGNATION S—STOCK NO. U—USAGE

PARTS LIST

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125√
RIVET BASIC CODE NAS523
BB—MS20426AD
BJ—MS20470AD

SEE 0—70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0—70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
X ±.1 XX ±.03 XXX ±.010
ANGULAR PER 0—70902

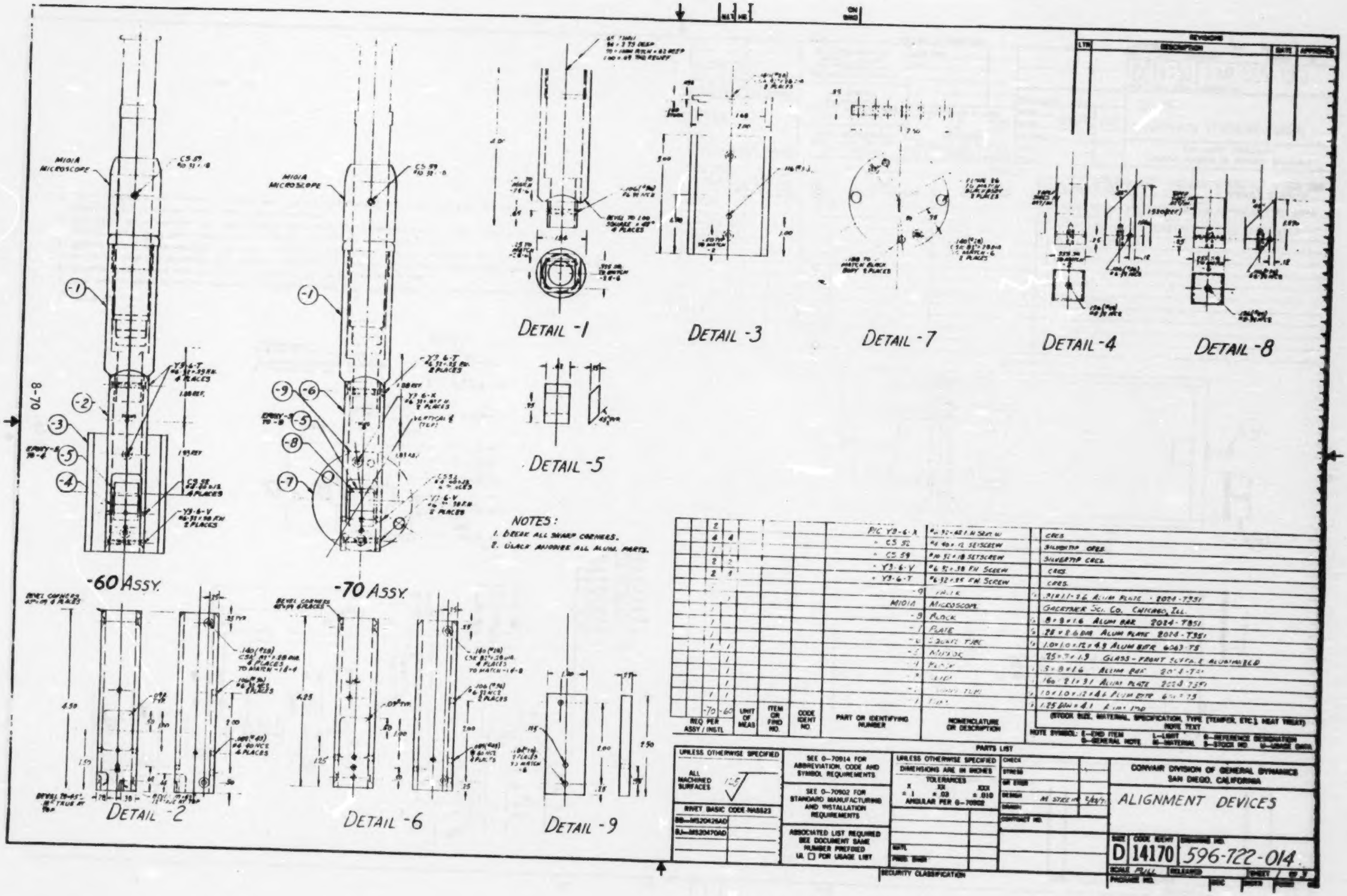
CHECK
STRESS
GR ENGR
DESIGN 1/8/71
DRAWN
CONTRACT NO.
MATL
PROD. ENGR
SECURITY CLASSIFICATION

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

MODIFIED WAVENUMBER DRIVE

SIZE D CODE IDENT 14170 DRAWING NO. 596-722-013
SCALE FULL RELEASED SHEET 1 OF 1
PACKAGE NO. DOC DISTR

REVISIONS
LTR DESCRIPTION DATE APPROVED



NOTES:
1. BREAK ALL SHARP CORNERS.
2. BLACK ANODIZE ALL ALUM. PARTS.

PARTS LIST

REQ PER ASSY / INSTL -70	REQ PER ASSY / INSTL -60	UNIT OF MEAS	ITEM OR FIND NO.	CODE IDENT NO	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	NOTE	(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT
2					P/C Y3-6-X	#6-32×.62 FH SCREW		CRES
4	4				CS 52	#4-40×.12 SETSCREW		SILVERTIP CRES
1	1				CS 59	#10-32×.18 SETSCREW		SILVERTIP CRES
2	2				Y3-6-V	#6-32×.38 FH SCREW		CRES
2	4				Y3-6-T	#6-32×.25 FH SCREW		CRES
					-9	PLATE		.31×1.1×3.6 ALUM PLATE 2024-T351
	1				M101A	MICROSCOPE		GAERTNER SCI. CO. CHICAGO, ILL.
1					-8	BLOCK		.8×.8×1.6 ALUM BAR 2024-T351
1					-7	PLATE		.25×2.6 DIA ALUM PLATE 2024-T351
1					-6	SQUARE TUBE		1.0×1.0×.12×4.9 ALUM BAR 6063-T5
1	1				-5	MIRROR		.75×.7×1.9 GLASS-FRONT SURFACE ALUMINIZED
	1				-4	BLOCK		.5×.8×1.6 ALUM BAR 2024-T351
	1				-3	PLATE		.160×2.1×3.1 ALUM PLATE 2024-T351
	1				-2	SQUARE TUBE		1.0×1.0×.12×4.6 ALUM BAR 6063-T5
1	1				-1	TUBE		1.25 DIA×4.1 ALUM ROD

NOTE SYMBOL: E—END ITEM G—GENERAL NOTE L—LIMIT M—MATERIAL R—REFERENCE DESIGNATION S—STOCK NO U—USAGE DATA

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125√

RIVET BASIC CODE NAS523
BB—MS20426AD
BJ—MS20470AD

SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
X ±.1 XX ±.03 XXX ±.010
ANGULAR PER 0-70902

MATL
FINISH

CHECK
STRESS
GP ENGR
DESIGN M STREIN 3/23/71
DRAWN
CONTRACT NO.

SECURITY CLASSIFICATION

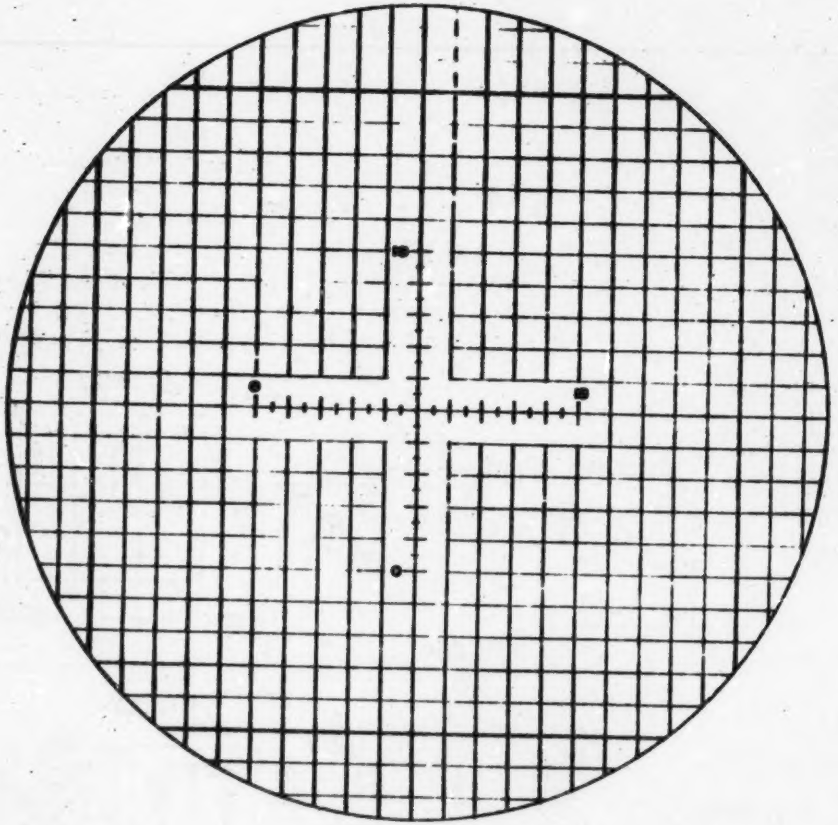
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

ALIGNMENT DEVICES

SIZE D CODE IDENT 14170 DRAWING NO. 596-722-014

SCALE FULL RELEASED SHEET 1 OF 3
PROGRAM NO.

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES √	SEE 0-70014 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES .X ±.1 .XX ±.03 .XXX ±.010 ANGULAR PER 0-70002	CHECK STRESS GR ENGR DESIGN DRAWN [illegible] CONTRACT NO.
SHEET BASIC CODE-NUMBER	SEE 0-70002 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS		
	ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED PL ☐ FOR PARTS LIST UL ☐ FOR USAGE LIST	ENGR. PROJ. ENGR.	

SECURITY CLASSIFICATION

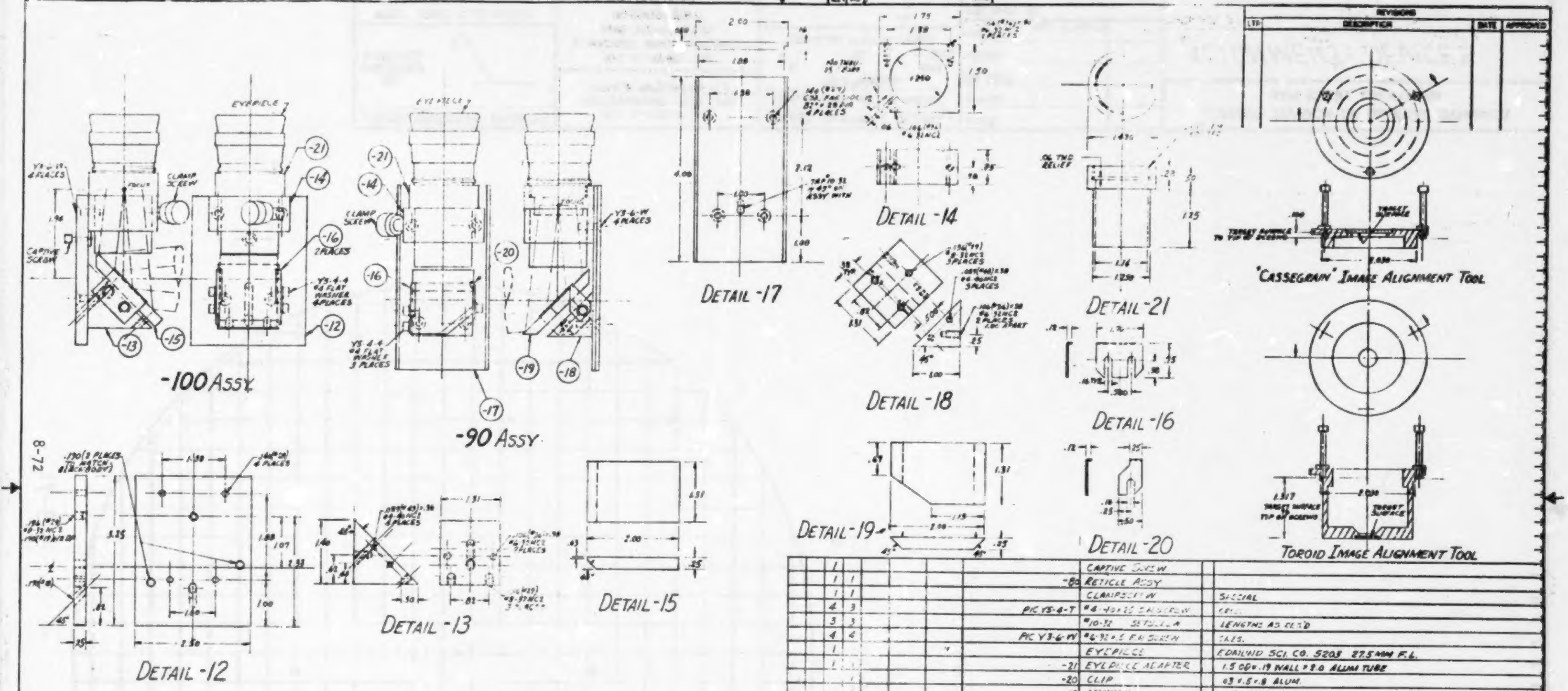
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

ALIGNMENT DEVICES

SIZE	CODE IDENT	DRAWING NO.
C	14170	596-722-014

SCALE | RELEASED | SHEET 2 OF 3

PACKAGE NO. | DOC | DISTR | FORM



1						CAPTIVE SCREW	
1	1				-80	RETICLE ASSY	
1	1					CLAMPSCREW	SPECIAL
4	3				PIC Y5-4-T	#4-40x.25 SHCSCREW	CRES.
3	3					#10-32 SETSCREW	LENGTHS AS REQ'D
4	4				PIC Y3-6-W	#6-32x.5 F.H.SCREW	CRES.
1						EYEPIECE	EDMUND SCI. CO. 5203 27.5 MM F.L.
1					-21	EYEPIECE ADAPTER	1.5 OD x .19 WALL x 2.0 ALUM TUBE
	1				-20	CLIP	.03 x .5 x .8 ALUM.
	1				-19	MIRROR	1.4 x 2.1 PLATE GLASS
	1				-18	MIRROR BLOCK	1 x 1 x 1.4 ALUM.
	1				-17	MOUNTING PLATE	.16 x 2 x 4 ALUM. PLATE
2	1				-16	CLIP	.03 x 1 x .8 ALUM.
1					-15	MIRROR	1.4 x 2.1 PLATE GLASS
1	1				-14	EYEPIECE HOLDER	.75 x 1.6 x 1.9 ALUM.
1					-13	MIRROR BLOCK	1.9 x 1.5 x 1.4 ALUM.
1					-12	BLACKBODY MTG PLATE	.25 x 2.6 x 3.3 ALUM. PLATE
-100 REQ PER ASSY / INSTL	-90 REQ PER ASSY / INSTL	UNIT OF MEAS	ITEM OR FIND NO.	CODE IDENT NO	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT

NOTE SYMBOL: E—END ITEM G—GENERAL NOTE L—LIMIT M—MATERIAL R—REFERENCE DESIGNATION S—STOCK NO. U—USAGE DATA

PARTS LIST

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES √

RIVET BASIC CODE-NAS523
BB—MS20426AD
BJ—MS20470AD

SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
X ±.1 XX ±.03 XXX ±.010
ANGULAR PER 0-70902

MATL
PROD ENGR
SECURITY CLASSIFICATION

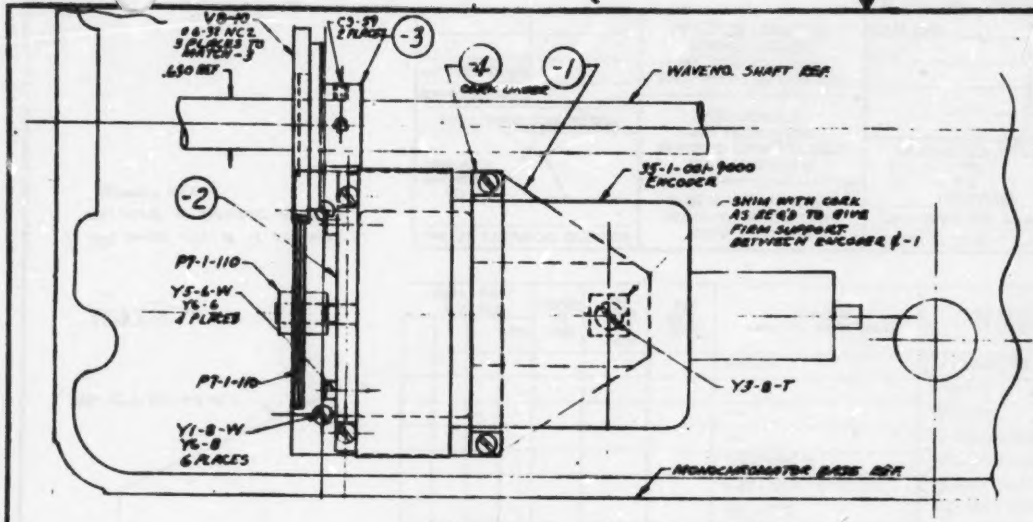
CHECK
STRESS
GR ENGR
DESIGN AL STRENT 2/9/71
DRAWN
CONTRACT NO.

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

ALIGNMENT DEVICES

SIZE D CODE IDENT 14170 DRAWING NO. 596-722-014
SCALE FULL RELEASED SHEET [illegible]
PACKAGE NO.

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

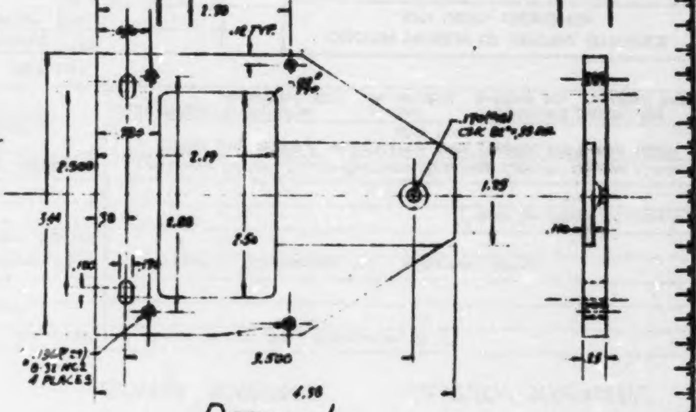


-60 ASSY.

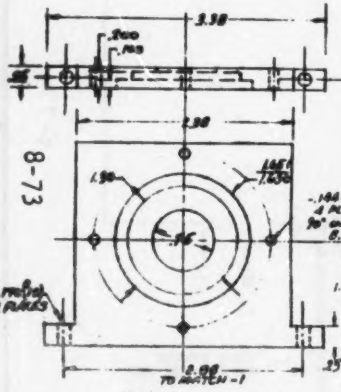
(BOTTOM VIEW OF MONOCHR.)

NOTES:

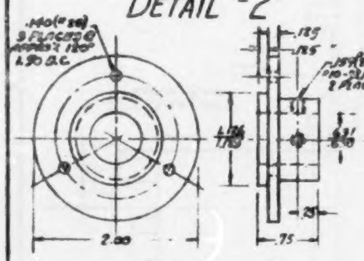
1. BREAK ALL SHARP CORNERS.
2. PAINT -1,& -2 FLAT BLACK.
3. FACE & RADIAL RUNOUT VB-10 AFTER INSTALL. .001 T.I.R.



DETAIL -1



DETAIL -2



DETAIL -3

GEAR BEARING FACES AND BORE TO BE DEAD TRUE & CONCENTRIC.

REQ PER ASSY / INSTL			-60	UNIT OF MEAS.	ITEM OR FIND NO.	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	NOTE	(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT
			1				-4	CLAMP		.063 × .38 × 7.7 2024-T3 ALUM. SHEET BEND TO FIT ENCODER
			A/R					CORK		
			2				PIC CS-59	#10-32 × .18 SETSCREW		SILVERTIP
			6				• Y6-8	#8 LOCKWASHER		
			4				• Y6-6	#6 LOCKWASHER		
			1				• Y3-8-T	#8-32 × .25 F.H.		
			4				• Y1-8-W	#8-32 × .5 FILL. HD.		
			4				• Y5-6-W	#6-32 × .5 S.H		
			1				MODEL 35-1-001-9000	ENCODER		DYNAMICS RESEARCH CORP, STONEHAM, MASS.
			1				PIC PT-1-110	GEAR, ANTIBACKLASH		48 PITCH, .101 FACE, 2.292 P.D., 2.333 O.D., 110 TOOTH .2498 BORE +.0005 -.0000
			1				PIC VB-10	GEAR, DIFFERENTIAL END		48 PITCH, .187 FACE, 2.292 P.D., 2.333 O.D., 110 TOOTH, 1.125 BORE +.0005 -.0000
			1				-3	HUB		2.0 DIA × .9 2024-T3 ALUM ROD
			1				-2	UPRIGHT		.25 × 2.6 × 3.5 2024-T3 ALUM PLATE
			1				-1	BASE		.25 × 3.3 × 4.5 2024-T3 ALUM PLATE

NOTE SYMBOL: E—END ITEM G—GENERAL NOTE L—LIMIT M—MATERIAL R—REFERENCE DESIGNATION S—STOCK NO. U—USAGE DATA

PARTS LIST

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125 √

RIVET BASIC CODE-NAS523
BB—MS20426AD
BJ—MS20470AD

SEE 0—70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0—70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED
SEE DOCUMENT SAME NUMBER PREFIXED
UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ±.1 .XX ±.03 .XXX ±.010
ANGULAR PER 0—70902

MATL
PROD. ENGR

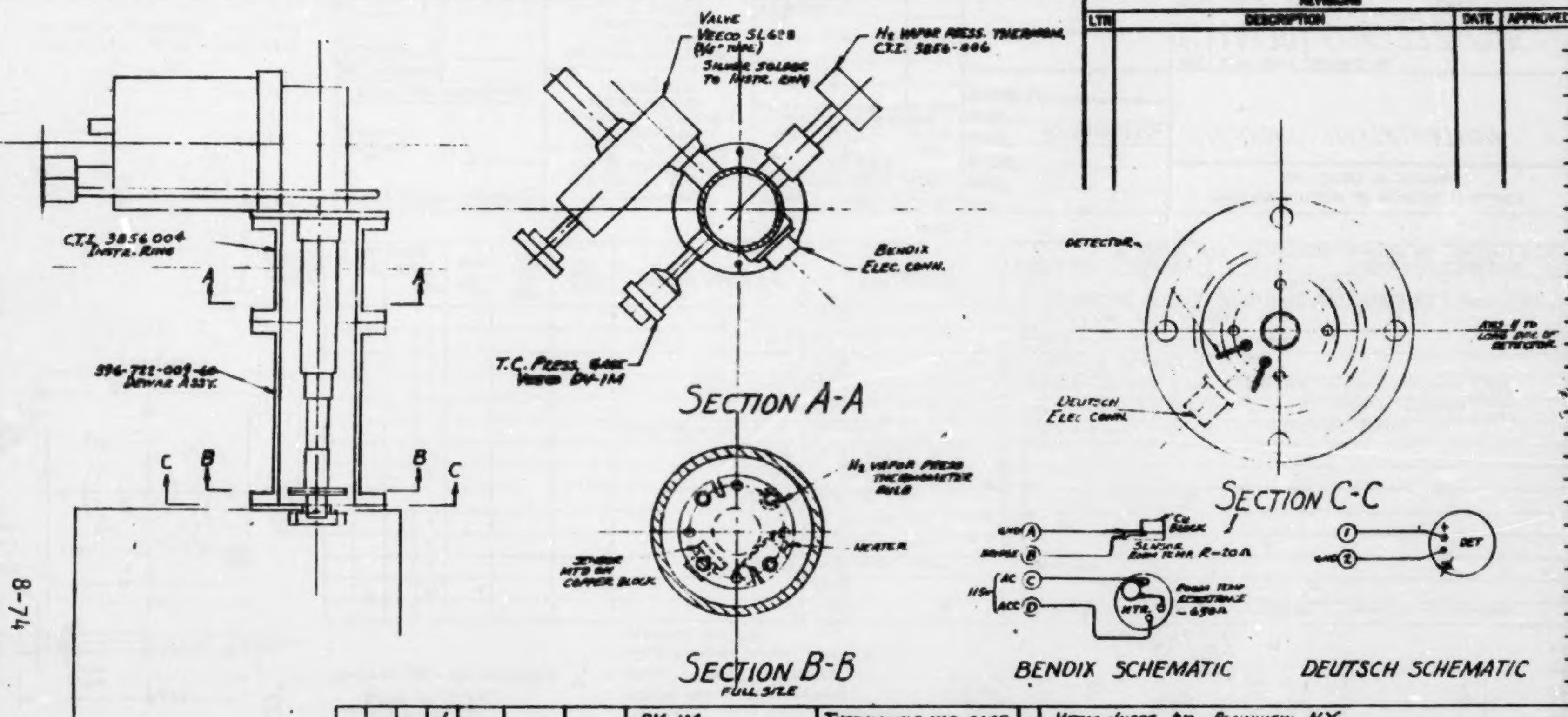
CHECK
STRESS
GR ENGR
DESIGN M STREIFF 3/8/71
DRAWN
CONTRACT NO.

SECURITY CLASSIFICATION

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

ENCODER INSTALLATION

SIZE C
CODE IDENT 14170
DRAWING NO. 596-722-015
SCALE FULL
RELEASED
SHEET 1 OF 1
PACKAGE NO.
DOC
DISTR
FORM


REVISIONS
LTR
DESCRIPTION
DATE
APPROVED
C.T.I. 3856 004 INSTR. RING
596-722-009-60 DEWAR ASSY.
A
B
C
VALVE VEECO SL628 (1/4" TUBE) SILVER SOLDER TO INSTR. RING
H2 VAPOR PRESS. THERMOM. C.T.I. 3856-006
BENDIX ELEC. CONN.
T.C. PRESS. GAGE VEECO DV-1M
SECTION A-A
H2 VAPOR PRESS THERMOMETER BULB
HEATER
SENSOR MTD ON COPPER BLOCK
SECTION B-B
FULL SIZE
DETECTOR
DEUTSCH ELEC CONN.
AXIS ‖ TO LONG DIM. OF DETECTOR
SECTION C-C
GND A
SIGNAL B
115~ AC C
ACC D
CU BLOCK
SENSOR ROOM TEMP. R-20Ω
ROOM TEMP RESISTANCE -650Ω
HTR.
BENDIX SCHEMATIC
1
GND 2
DET
DEUTSCH SCHEMATIC
596-722-011-60 REF.

REQ PER ASSY / INSTL	UNIT OF MEAS	ITEM OR FIND NO.	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION		NOTE TEXT (STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT)
1				DV-1M	THERMOCOUPLE VAC. GAGE		VEECO INSTR. INC., PLAINVIEW, N.Y.
1				SL625	VACUUM VALVE		" " " "
1				596-722-009-60	DEWAR ASSY		
1				3854004	INSTRUMENTATION RING		CRYOGENIC TECHNOLOGY INC., WALTHAM, MASS.
1				—	H2 VAPOR PRESS. THERMOM.		" " "
1				—	HEATER		" " " (PART OF MODEL 20 SYSTEM)
1				—	SENSOR		" " " " " "
1				06791	Hg-DOPED GE DETECTOR		0.2×2.0mm 90 FOV SANTA BARBARA RESEARCH CENTER GOLETA CALIF.
60							

NOTE SYMBOL: E—END ITEM G—GENERAL NOTE L—LIMIT M—MATERIAL R—REFERENCE DESIGNATION S—STOCK NO. U—USAGE DATA

PARTS LIST

NOTES:

1. BE SURE PIN A IS CONNECTED TO SIDE OF SENSOR NEXT TO COPPER BLOCK.

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES √

RIVET BASIC CODE-NAS523
BB—MS20426AD
BJ—MS20470AD

SEE 0—70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0—70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ±.1 .XX ±.03 .XXX ±.010
ANGULAR PER 0—70902

MATL
PROD. ENGR

CHECK		
STRESS		
GR ENGR		
DESIGN	N STREIFF	3/3/71
DRAWN		
CONTRACT NO.		

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

CRYOCOOLER EQUIPMENT

SIZE	CODE IDENT	DRAWING NO.
C	14170	596-722-016

SCALE 1/1 NOTED RELEASED SHEET 1 OF 2
PACKAGE NO. DOC DISTR FORM

SECURITY CLASSIFICATION

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

Detector Specification

Type: Mercury-doped germanium

Wavelength of Interest: 3.0 to 5.5 and 7.0 to 13.5 microns

Element Size: 0.2 x 2.0 mm (see accompanying drawing)

Field of View: Approximately 50° (10 mm baffle at 5 mm)

Mounting: Copper base with detector attached to terminals; mounting may be electrically insulated from cold finger.

Operating Temperature: 26°K (closed cycle mechanical cooler)

Blackbody D^* (50°, 500°K, 400 Hz): $\geq 1 \times 10^{10}$ cm $Hz^{\frac{1}{2}}$/watt

Effective Source Impedance: 10^6 ohms nominal; 10^5 to 10^7 ohms acceptable

Application: Ground based field spectrometer

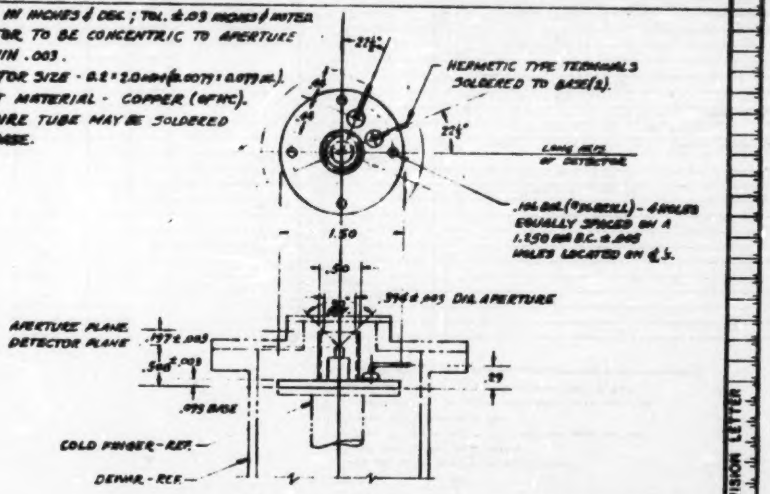
Chopping Frequency: 400-2000 Hz

Responsivity: As uniform over the surface as possible

Performance data to be supplied by manufacturer.

NOTES:

1. ALL DIM. IN INCHES & DEG.; TOL. ±.03 INCHES & NOTED
2. DETECTOR TO BE CONCENTRIC TO APERTURE WITHIN .003.
3. DETECTOR SIZE - 0.2 × 2.0 MM (0.0079 × 0.079 IN.).
4. MOUNT MATERIAL - COPPER (OFHC).
5. APERTURE TUBE MAY BE SOLDERED TO BASE.



DO NOT SCALE DRWG.

GENERAL DYNAMICS
CONVAIR DIVISION
SAN DIEGO, CALIFORNIA

SIZE A | CODE IDENT 14170 | DRAWING NO. DETECTOR SPEC. DRWG.
SCALE FULL | RELEASED | SHEET

REVISION LETTER

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES √
RIVET BASIC CODE-NAS523
EB—MS20426AD
BJ—MS20470AD

SEE 0—70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS
SEE 0—70802 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS
ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ± .1 .XX ± .03 .XXX ± .010
ANGULAR PER 0—70802
MATL
PROD. ENGR

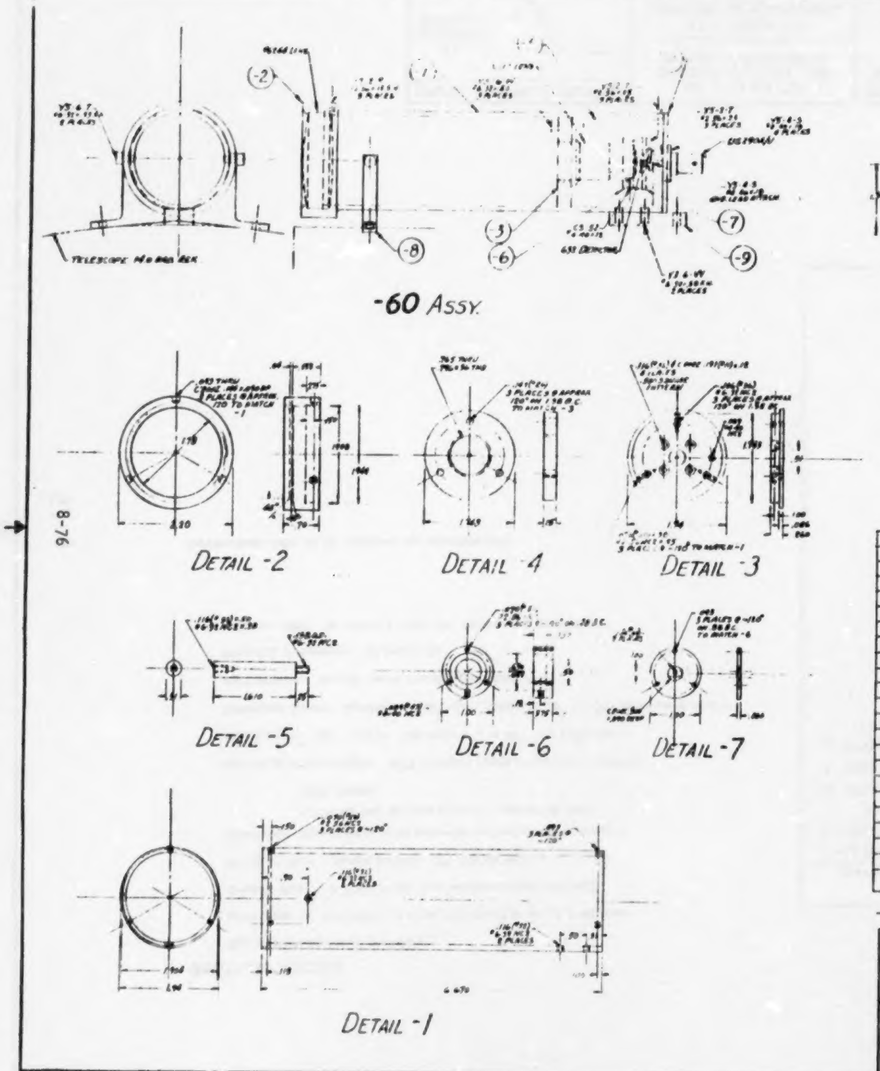
CHECK
STRESS
GR ENGR
DESIGN M Streiff 3/3/71
DRAWN
CONTRACT NO.

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

CRYOCOOLER EQUIPMENT

SIZE C | CODE IDENT 14170 | DRAWING NO. 596-722-016
SCALE — | RELEASED | SHEET 2 OF 2
PACKAGE NO. | DOC | DISTR | FORM 8037

SECURITY CLASSIFICATION



NOTES:

1. BREAK ALL SHARP CORNER APPROX .020 × 45°
2. BLACK ANODIZE ALL ALUM PARTS
3. ATTACH #4 SOLDER LUG TO ONE DETECTOR LEAD PER ASB.
4. REMOVE SHELL FROM DETECTOR.
5. DEVIATIONS FROM ANGULAR POSITION OF HOLE PATTERNS SHOWN ARE PERMISSIBLE EXCEPT THOSE FOR -8 & -9.
6. INSULATE BNC FITTING FROM HOUSING (GLASS TAPE & FIBER WASHERS).

REQ PER ASSY / INSTL -6?	UNIT OF MEAS	ITEM OR FIND NO	CODE IDENT NO	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	NOTE SYMBOL	(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT
1				C3S?	#4-40 × 1/8 S.H. SETSCREW		CRES [illegible]
2				Y3 6 W	#6-32 × .50 F.H		"
3				Y3 6 W	#6-32 × .50 S.H		"
2				Y3 6 7	#6-32 × .75 S.H.		"
5				Y3 4 3	#4-40 × .18 S.H		"
6				Y3-2 T	#2-56 × .25 S.H.		"
3				Y3-2 R	#2-56 × .18 S.H		"
1				-9	SPACER		.31 × .6 × 1.3 ALUM PLATE 2024-T3
1				-8	BRACKET		.25 × 3.6 × 1.3 ALUM PLATE 2024-T3
1				UG??? A/U	CONNECTOR-BNC		
1				632	DETECTOR (InAs PV)		[illegible]
1				C115	FIELD LENS		[illegible] OPTICAL (SPACER) 49 × 9.4 3.66 [illegible] F.L.
1				#6240	OBJECTIVE LENS		[illegible] Co. 49mm O.D. 147mm F.L. Barrington N.J.
1				-7	PLATE		1.00 DIA × .06 EPOXY FIBERGLASS
1				-6	MOUNT		1.05 DIA × .6 ALUM ROD 2024-T3
3				-5	SPACER		.31 DIA × 2.0 ALUM ROD "
1				-4	LENS MOUNT		.25 × 1.8 × 1.8 ALUM PLATE "
1				-3	END PLATE		.31 × 2.0 × 2.0 ALUM PLATE "
1				-2	COLLAR		.75 × 2.5 × 2.5 ALUM PLATE "
1				-1	TUBE		2.0 O.D. × .12 WALL × 6.? ALUM PIPE 2021-T351

NOTE SYMBOL: E—END ITEM G—GENERAL NOTE L—LIST M—MATERIAL R—REFERENCE DESIGNATION S—STOCK NO. U—USAGE DATA

PARTS LIST

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES 125√
RIVET BASIC CODE NAS523
BB—MS20426AD
DD—MS20470AD

SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED
SEE DOCUMENT SAME NUMBER PREFIXED
IA ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ± .1 .XX ± .03 .XXX ± .010
ANGULAR PER 0-70802

MATL
PROD ENGR
SECURITY CLASSIFICATION

CHECK
STRESS
GR ENGR
DESIGN [illegible] 3/6/?
CONTRACT NO.

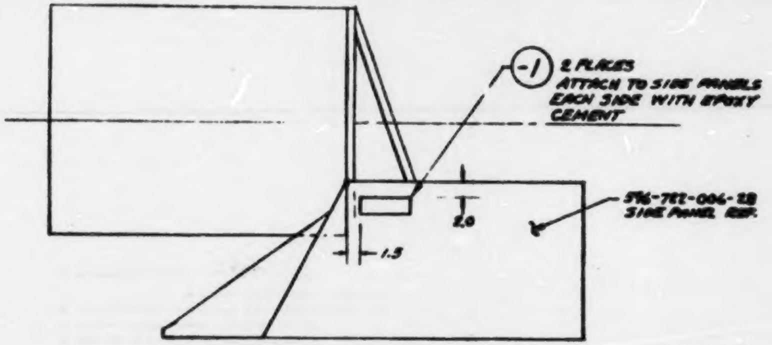
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

SOURCE SYNCH. RECEIVER

SIZE D CODE IDENT 14170 DRAWING NO. 596-722-017
SCALE RELEASED SHEET 1 OF 1
PACKAGE NO.

LTR	DESCRIPTION	DATE	APPROVED

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



TYPICAL INSTALLATION
APPROX. 0.1 SIZE

GENERAL DYNAMICS - CONVAIR AEROSPACE
ENVIRONMENTAL SCIENCES

SYSTEM FOR
REMOTE OPTICAL SENSING OF EMISSION

NOTES:

1. BACKGROUND TO BE WHITE WITH BLACK BORDER AND BLACK LETTERS EXCEPT THE CAPITAL LETTERS R, O, S AND E IN THE BOTTOM ROW TO BE BRIGHT RED.

2. GOTHIC TYPE TO BE USED; RAISED LETTERS AND BORDER.

REQ PER ASSY / INSTL		UNIT OF MEAS	ITEM OR FIND NO.	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT
-70	-60						
2	2				-1	NAMEPLATE	.062 x 2.5 x 7.5 ALUM. SHEET (APPROX. SIZE)

NOTE SYMBOL: E—END ITEM G—GENERAL NOTE L—LIMIT M—MATERIAL R—REFERENCE DESIGNATION S—STOCK NO. U—USAGE DATA

PARTS LIST

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES √
RIVET BASIC CODE-NAS523
BB—MS20426AD
BJ—MS20470AD

SEE 0—70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0—70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT BANK NUMBER PREFIXED UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ±.1 .XX ±.03 .XXX ±.010
ANGULAR PER 0—70902

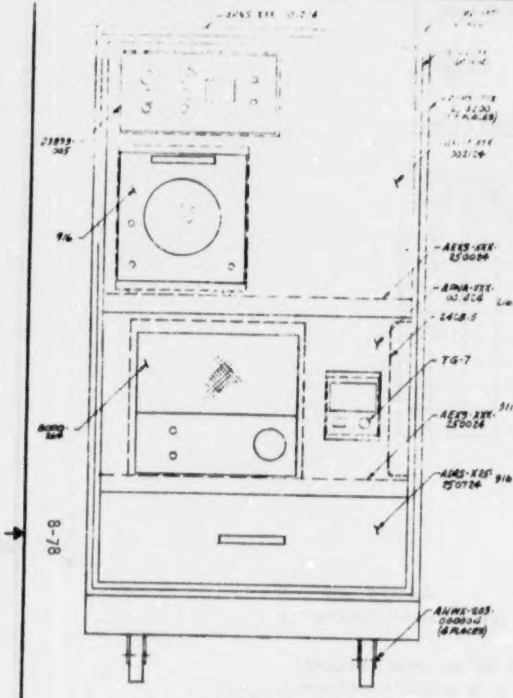
MATL
PROD. ENGR
SECURITY CLASSIFICATION

CHECK
STRESS
GR ENGR
DESIGN M. STREET
DRAWN
CONTRACT NO.

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

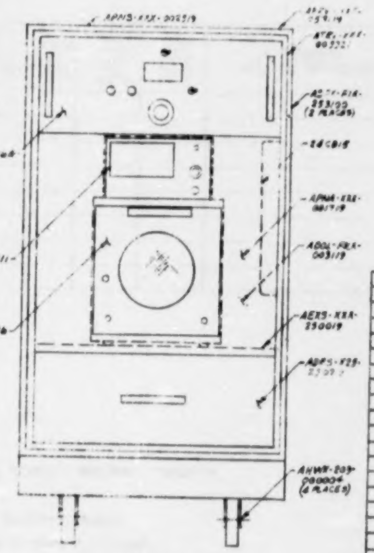
SYSTEM NAMEPLATE

SIZE C
CODE IDENT 14170
DRAWING NO. 596-722-018
SCALE FULL
RELEASED
SHEET 1 OF 1
PACKAGE NO.
DOC
FORM



-70 Assy.

26" wide × 27" deep × 51" high



-60 Assy.

21" wide × 27" deep × 40" high

NOTES:

1. This drawing for reference only.
2. Move handles on 916 from top to front & back (4 places).
3. Provide brackets for D3833-005 and 311.
4. Provide clips at rear of D3833-005, 916, 8000-004 & 311.
5. Emcor parts color: EN2-60 gold.
6. Total current: -60 Assy = 12.5 amp start, 5.5 amp run.
   -70 Assy = 17.3 amp start; 12.3 amp run.
7. Estimated weight: -60 Assy ~ 219#
   -70 Assy ~ 270#

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

-70	-60	UNIT OF MEAS	ITEM OR FIND NO	CODE IDENT NO	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION		STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT	CURRENT START	CURRENT RUN
1					916 3/4-156	B.B. Cooler		Electro Optical Ind Santa Barbara, Calif		2.1
1					D3833-005	Cryo Controller		Cryogenic Technology Inc. Waltham, Mass.		0.1
1					Mod 20/70	Cryo Compressor		• •	-18	10.
1					TG-7	Thermocouple Indicator		Veeco, Plainview N.Y.		[illegible]
1					ATRV-XXX-004626	Temp Kit		Emcor II Ingersoll Products Chicago Ill.		
1					APNA-XXX-002124	Panel		•		
1					APNA-XXX-001424	Panel		•		
1					ADRS-XXS-250724	Drawer		•		
2					AEXS-XXX-250024	Eqmt Shelf		•		
1					ADOL-FXX-904224	Door		•		
2					ASPX-FIX-254220	Side Panel		•		
1					APNS-XXX-002124	Top Panel		•		
1					AFRV-XXT-294224	Frame		•		
1	1				24CB15	AC Plug Strip		Wager Elec. Phil. Pa.		
	1				216A 3/4-156	B.B. Temp Control		Electro Optical Inc. Santa Barbara Calif	18	2.8
	1				311 3/4-155	B.B. Alignment Control		•		0.3
					916 3/4-155	B.B. Cooler		•		9.2
					ATRV-XXX-20332	Temp Kit		Emcor II Ingersoll Products Chicago Ill.		
	4				AHWX-203-000004	4" Casters		•		
	1				APNA-XXX-221719	Panel		•		
	1				ADRS-XXS-252719	Drawer		•		
	1				AEXS-XXX-253019	Eqmt Shelf		•		
	1				ADOL-FXX-203119	Door		•		
	2				ASPX-FIX-253120	Side Panel		•		
	1				APNS-XXX-002519	Top Panel		•		
	1				AFRV-XXT-253119	Frame		•		
REQ PER ASSY / INST.										

NOTE SYMBOL: E—END ITEM G—GENERAL NOTE L—LIMIT M—MATERIAL R—REFERENCE DESIGNATION S—STOCK NO. U—USAGE DATA

PARTS LIST

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES √

SHEET BASIC CODE MARKED

SEE 0-70814 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70802 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED LA ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ± .1 .XX ± .03 .XXX ± .010
ANGULAR PER 0-70802

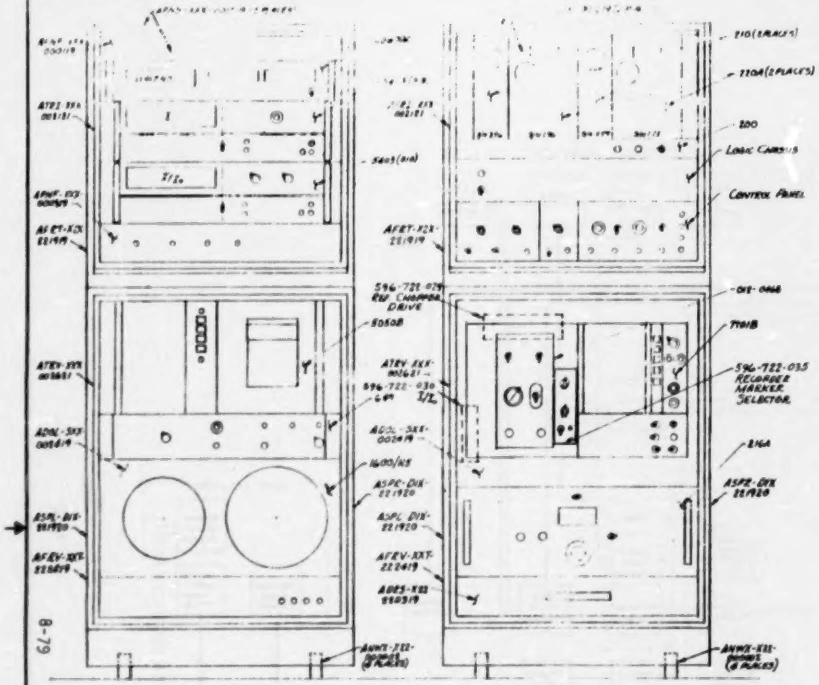
CHECK
STRESS
GR ENGR
DRAWN [illegible] [illegible]
CONTRACT NO.

SECURITY CLASSIFICATION

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

AUXILIARY STANDS

SIZE D
CODE IDENT 14170
DRAWING NO. 596-722-019
SCALE 1/4
RELEASED
SHEET 1 OF 1
PACKAGE NO.



-60 ASSY.

-70 ASSY.

NOTES:

1. THIS DRAWING FOR REFERENCE ONLY
2. EMCOR PARTS COLOR: EM2-60 GOLD
3. TOTAL CURRENT – 60 ASSY = 3 AMPS
   – 70 ASSY = 12 AMPS START; 8.7 AMPS RUN
4. ESTIMATED WEIGHT EACH ASSY ~ 370#

REVISIONS LTR	DESCRIPTION	DATE	APPROVED

REQ PER ASSY/INSTL -70	-60	UNIT OF MEAS	ITEM OR FIND NO	CODE IDENT NO	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT	CURRENT AMPS START	CURRENT AMPS RUN
1					596-722-029	REF CHOPPER DRIVE	GENERAL DYNAMICS CONVAIR SAN DIEGO CALIF.		
1					596-722-030	I/I₀ MODULE	" " " " "		
1					596-722-035	RECORDER MARKER SEL.	" " " " "		
2					MODEL 210 [illegible]	SELECTIVE AMPLIFIER	PRINCETON APPLIED RESEARCH PRINCETON, NEW JERSEY		
2					MODEL 120A [illegible]	LOCK IN AMPLIFIER	" " "		
1					MODEL 800 —	NIMBIN CHASSIS & PWR SUPPLY	" " "		0.9
1					— —	LOGIC CHASSIS	GENERAL DYNAMICS - CONVAIR SAN DIEGO, CALIF.		0.3
1					— —	CONTROL PANEL	GENERAL DYNAMICS - CONVAIR SAN DIEGO, CALIF.		–
1					MODEL 012-0466	[illegible] DRIVE CONTROL	PERKIN ELMER NORWALK, CONN.		1.5
1					MODEL 7701B [illegible]	STRIP CHART RECORDER	HEWLETT PACKARD PALO ALTO, CALIF. ([illegible])		0.6
1					MODEL 216A [illegible]	B.B. TEMPERATURE CONTROL	ELECTRO OPTICAL IND. SANTA BARBARA, CALIF.	8.9	6.6
	1				MODEL [illegible]	[illegible] COUNTER	[illegible] VAN NUYS, CALIF. ([illegible])		[illegible]
	1				MODEL 5403 [illegible]	DIGITAL VOLTMETER	DANA LAB., INC. IRVINE, CALIF. (MODEL 605 PLUG IN)		[illegible]
	1				MODEL 5403 [illegible]	DIGITAL VOLTMETER	" " " " (MODEL 400 PLUG IN)		[illegible]
	1				MODEL 5050B [illegible]	DIGITAL RECORDER (PRINTER)	HEWLETT-PACKARD PALO ALTO, CALIF.		[illegible]
	1				MODEL 649	DATA COUPLER CONTROL	[illegible] INC. [illegible], CALIF.		[illegible]
	1				1600/HS [illegible]	DIGITAL TAPE RECORDER	KENNEDY CO. ALTADENA, CALIF.		[illegible]
1					ADES-X22-220319	FRAME (9")	EMCOR II INGERSOLL PRODUCTS CHICAGO, ILL.		
4					ANWX-220-000???	2" DIA CASTERS	"		
[illegible]					ATRI-XXX-001181	TRIM KIT	"		
					ATEV-XXX-00[illegible]	TRIM KIT	"		
	1				APNT-XXX-001[illegible]	PANEL ([illegible]")	"		
	1				APNT-XXX-000919	PANEL ([illegible]")	"		
	1				ADOL-SXX-00[illegible]19	DOOR	"		
	1				ASPR-DIX-221920	RIGHT SIDE PANEL	"		
1	1				ASPL-DIX-221920	LEFT SIDE PANEL	"		
2	2				APNS-XXX-[illegible]	TOP PANEL & [illegible] PANEL	"		
1	1				AFRT-X2X-221919	FRONT FRAME	"		
1	1				AFEV-XXT-222419	VERTICAL FRAME	"		

NOTE SYMBOLS: I–END ITEM L–LIMIT R–REFERENCE DESIGNATION
G–GENERAL NOTE M–MATERIAL S–STOCK NO. U–USAGE

PARTS LIST

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES √

RIVET BASIC CODE NAS523

SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
X ±.1 XX ±.03 XXX ±.010
ANGULAR PER 0-70902

SECURITY CLASSIFICATION

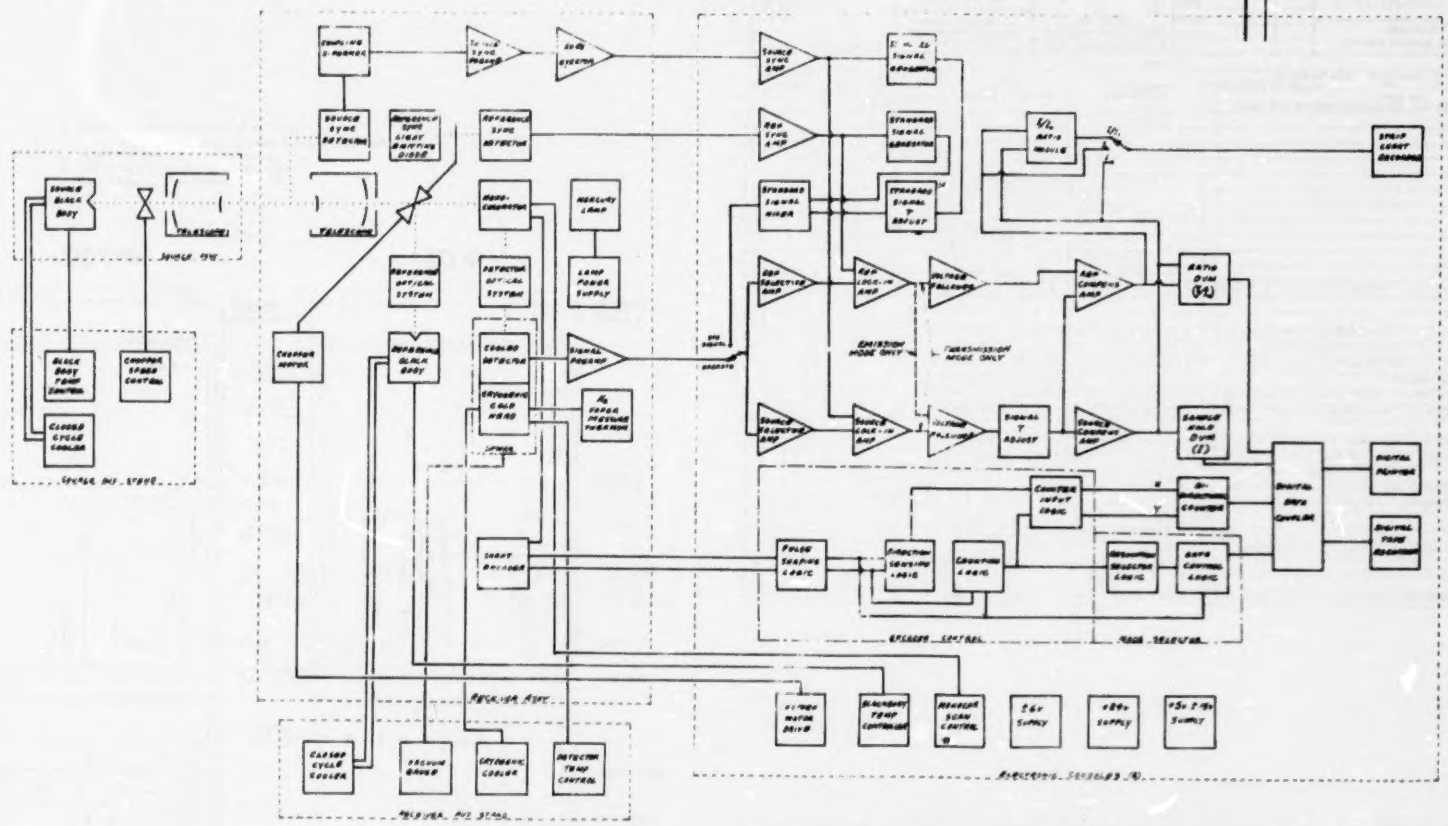
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

ELECTRONIC CONSOLES

SIZE D CODE IDENT 14170 DRAWING NO. 596-722-020

SCALE 1/4 SHEET 1 OF 2

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



UNLESS OTHERWISE SPECIFIED	SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	CHECK	
ALL MACHINED SURFACES √	SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS	TOLERANCES .X ±.1 .XX ±.03 .XXX ±.010 ANGULAR PER 0-70902	STRESS	
RIVET BASIC CODE NAS523	ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED PL ☐ FOR PARTS LIST UL ☐ FOR USAGE LIST	MAT'L	GP ENGR	
BB—MS20426AD		PROD ENGR	DESIGN	
BJ—MS20470AD			DRAWN E. Pollins	
			CONTRACT NO	

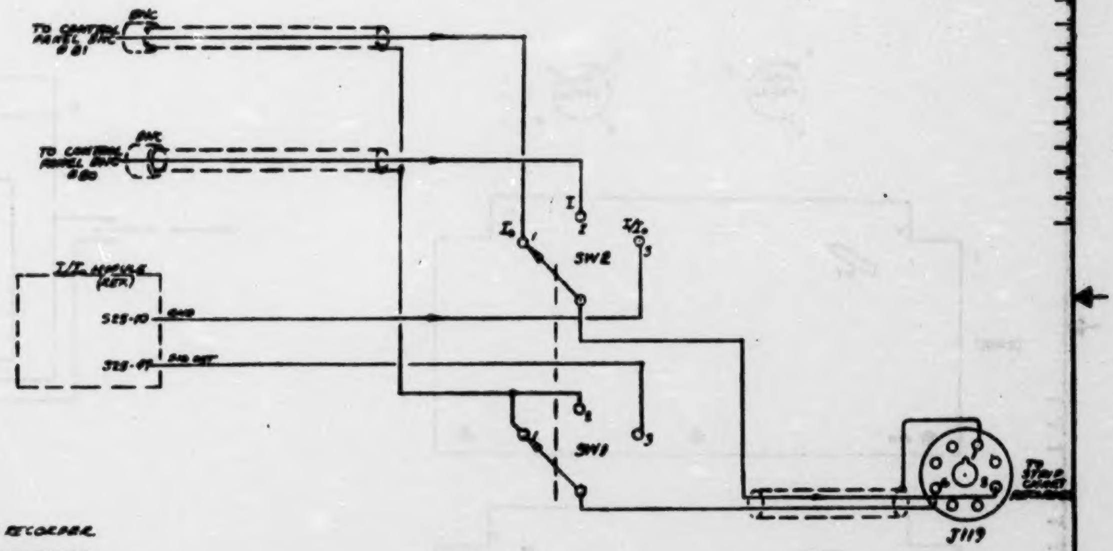
SECURITY CLASSIFICATION

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

SYSTEM BLOCK DIAGRAM

SIZE D
CODE IDENT 14170
DRAWING NO 596-722-021
SCALE —
RELEASED
SHEET 1 OF 1
PACKAGE NO
DOC
DISTR
FORM

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



NOTES:

1. SWITCH IS MOUNTED TO LEFT OF STRIP CHART RECORDER.
2. NOTE THAT I/I₀ MODULE IS NEG. TO GND.; THEREFORE, I/I₀ MODULE LEADS ARE REVERSED FROM NORMAL POSITION TO GIVE UPSCALE RECORDER DEFLECTION (STRIP CHART RECORDER INPUT MUST BE FLOATING).

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES ✓

RIVET BASIC CODE-NAS523
DB—MS20426AD
BJ—MS20470AD

SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED
SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ± .1
.XX ± .03
.XXX ± .010
ANGULAR PER 0-70902

MATL
PROD. ENGR

CHECK
STRESS
GR ENGR
DESIGN
DRAWN M Duff 7/27/71
CONTRACT NO

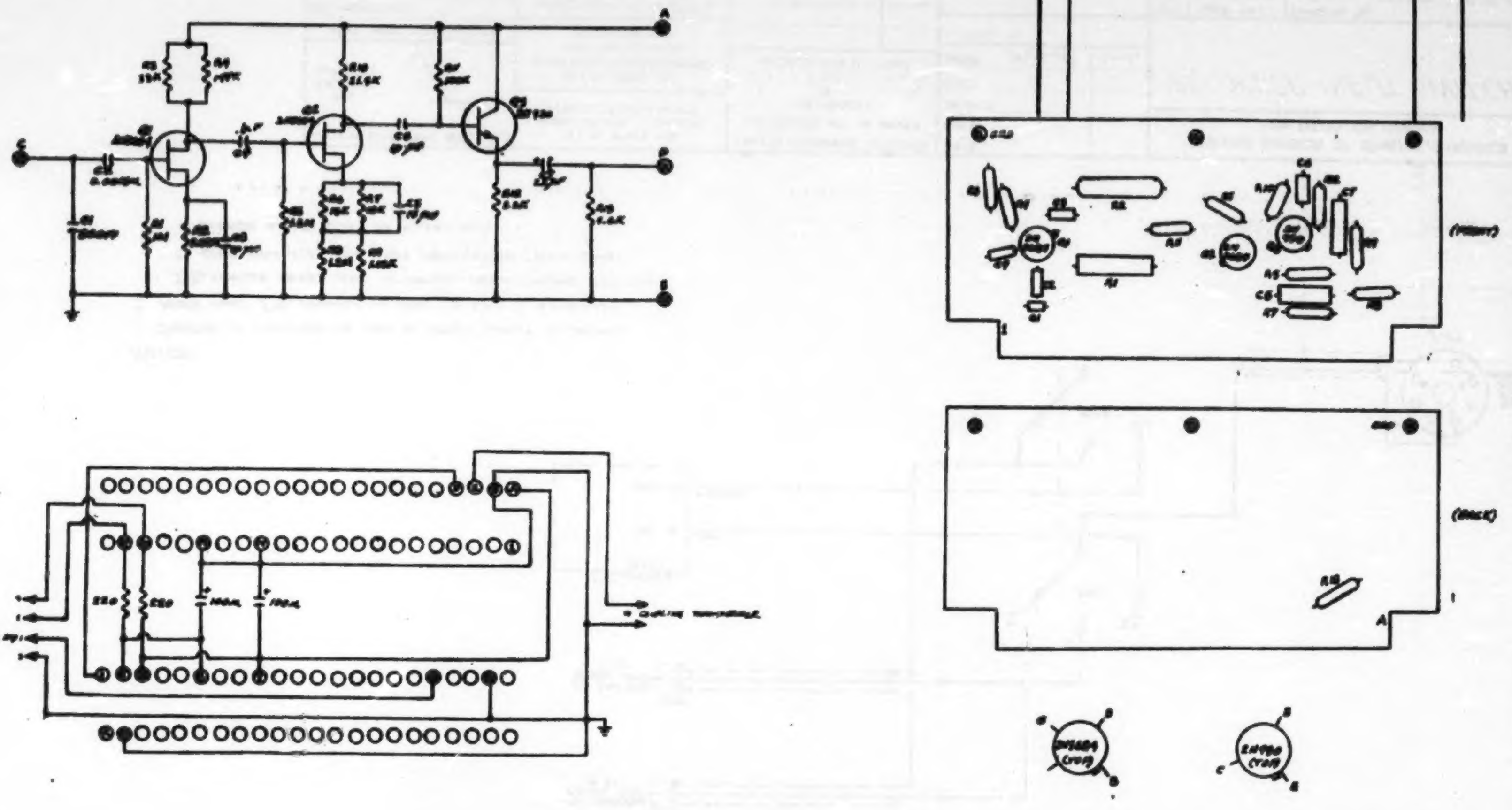
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

RECORDER INPUT SWITCH

SIZE C
CODE IDENT 14170
DRAWING NO. 596-722-022
SCALE
RELEASED
SHEET 1 OF 1
PACKAGE NO.
DOC
DISTR
FORM

SECURITY CLASSIFICATION

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



UNLESS OTHERWISE SPECIFIED

ALL MACHINED SURFACES √

RIVET BASIC CODE-NAS523

BD—MS20426AD

BJ—MS20470AD

SEE 0—70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0—70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED

PL ☐ FOR PARTS LIST

UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED

DIMENSIONS ARE IN INCHES

TOLERANCES

.X	.XX	.XXX
± .1	± .03	± .010

ANGULAR PER 0—70902

MATL

PROD. ENGR

SECURITY CLASSIFICATION

CHECK

STRESS

GR ENGR

DESIGN

DRAWN R. ROLLINS

CONTRACT NO.

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

SOURCE SYNC PREAMP

SIZE	CODE IDENT	DRAWING NO.
C	14170	596-722-023

SCALE

RELEASED

SHEET 1 OF 1

PACKAGE NO.

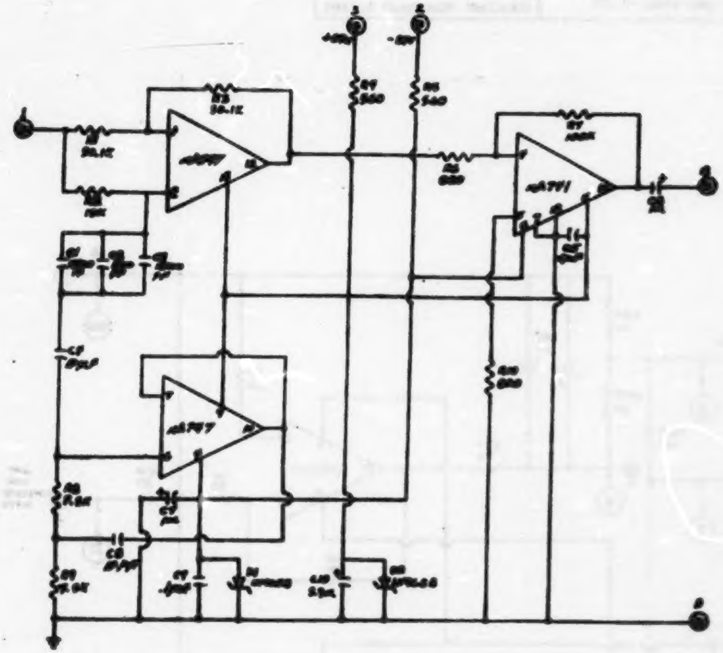
DOC

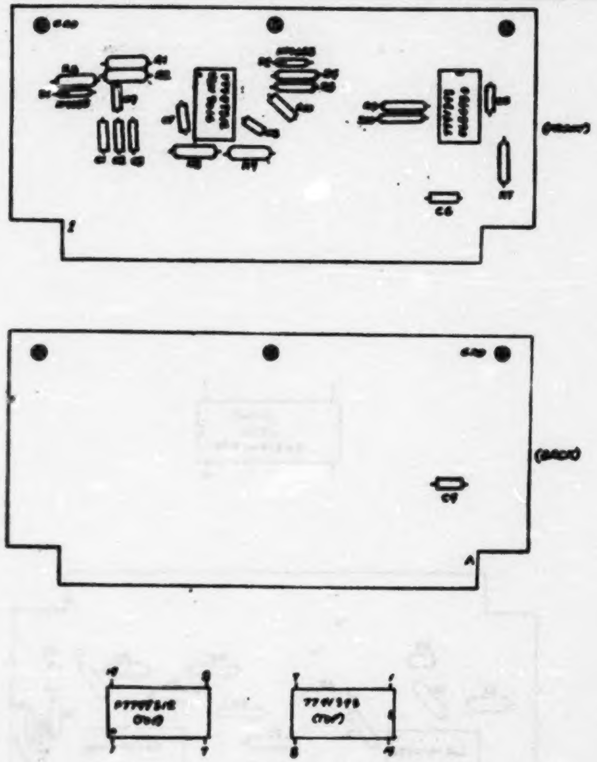
DISTR

FORM

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED





UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES √ RIVET BASIC CODE-NAS523 BB—MS20426AD BJ—MS20470AD	SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED PL ☐ FOR PARTS LIST UL ☐ FOR USAGE LIST	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES .X ±.1 .XX ±.03 .XXX ±.010 ANGULAR PER 0-70902 LIAIS. PROD. ENGR

CHECK
STRESS
GP ENGR
DESIGN
DRAWN R. ROLLINS
CONTRACT NO.

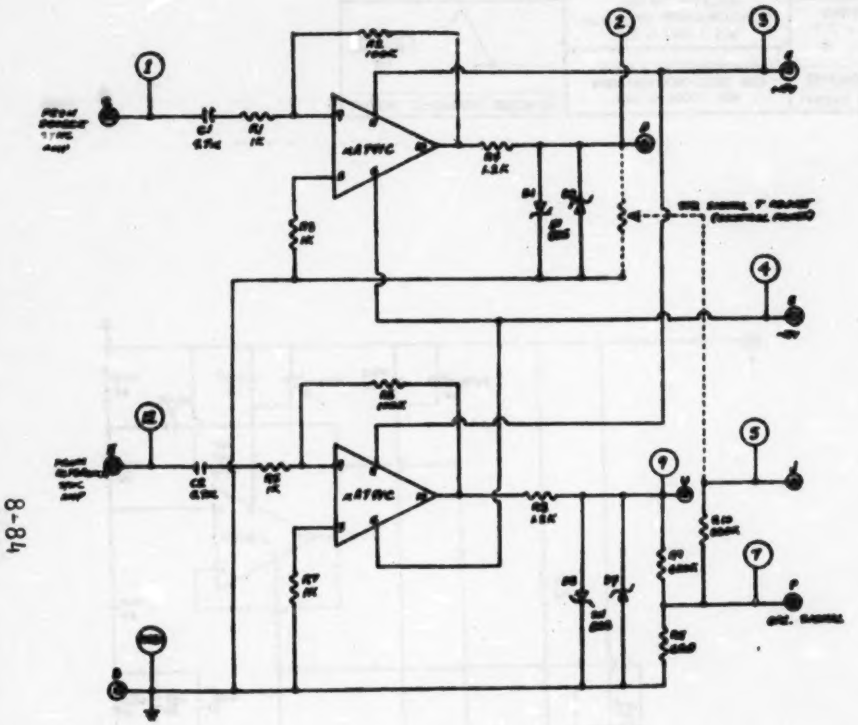
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

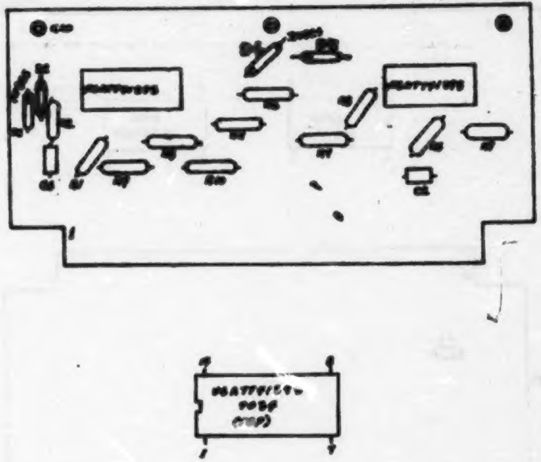
120 Hz GYRATOR

SIZE C
CODE IDENT 14170
DRAWING NO. 596-722-024
SCALE
RELEASED
SHEET 1 OF 1
PACKAGE NO.
DOC
DISTR
FORM 8017

SECURITY CLASSIFICATION

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED





UNLESS OTHERWISE SPECIFIED	SEE 0—70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	CHECK
ALL MACHINED SURFACES √	SEE 0—70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS	TOLERANCES .X ± .1 · .XX ± .03 · .XXX ± .010 ANGULAR PER 0—70902	STRESS GR ENGR DESIGN DRAWN R. ROLLINS
RIVET BASIC CODE-NAS523 BB—MS20426AD BJ—MS20470AD	ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED PL ☐ FOR PARTS LIST UL ☐ FOR USAGE LIST	MATL PROD. ENGR	CONTRACT NO.

SECURITY CLASSIFICATION

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

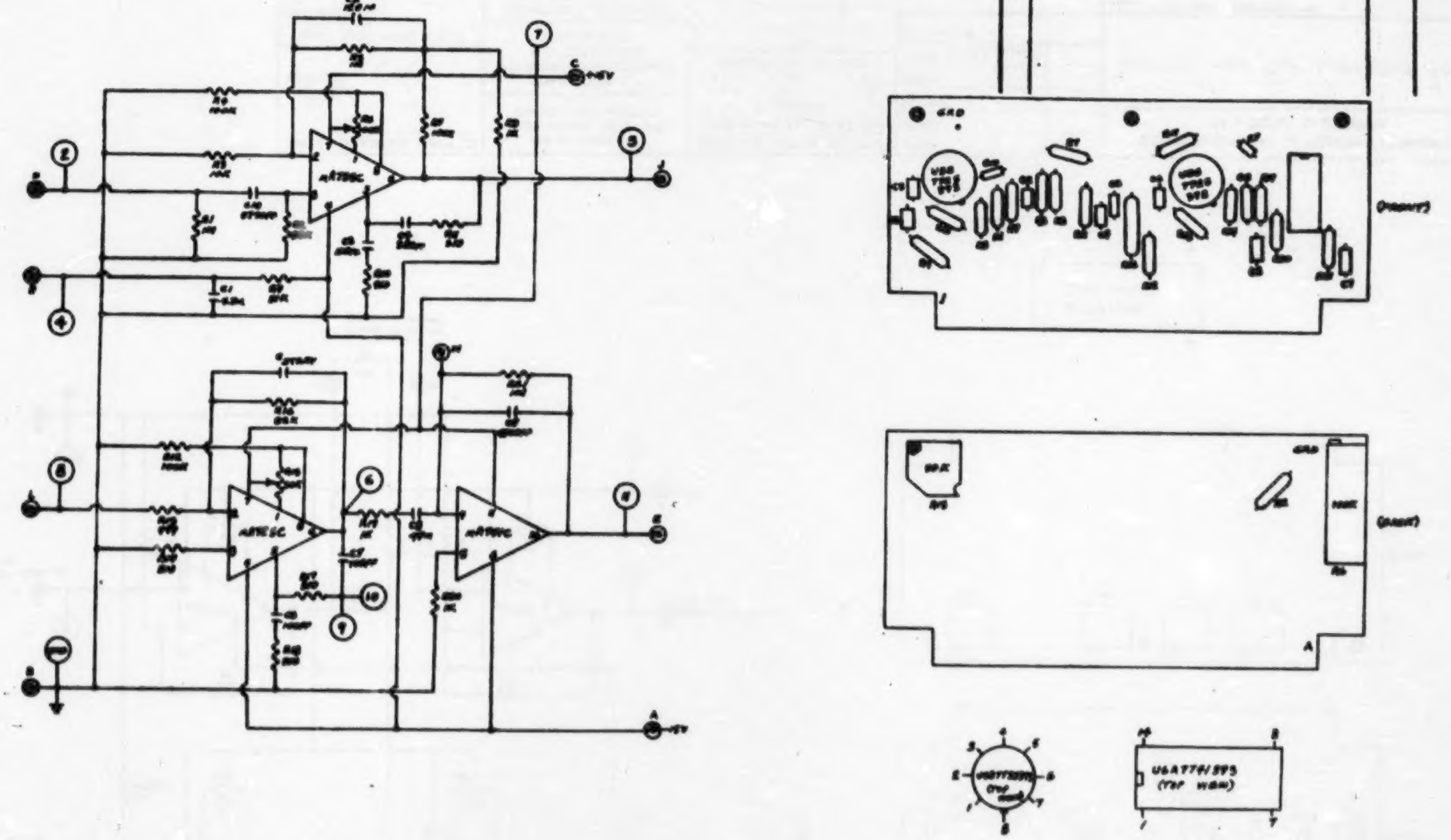
STANDARD SIGNAL GENERATOR

SIZE	CODE IDENT	DRAWING NO.
C	14170	596-722-025

SCALE · RELEASED · SHEET 1 OF 1

PACKAGE NO. · DOC · DISTR. · FORM 0817

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



UNLESS OTHERWISE SPECIFIED	SEE 0–70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	CHECK	
ALL MACHINED SURFACES √	SEE 0–70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS	TOLERANCES .X ±.1 .XX ±.03 .XXX ±.010 ANGULAR PER 0–70902	STRESS GR ENGR DESIGN DRAWN A. Rollins	
RIVET BASIC CODE-NAS523 DB—MS20426AD BJ—MS20470AD	ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED PL ☐ FOR PARTS LIST UL ☐ FOR USAGE LIST	MATL PROD. ENGR	CONTRACT NO.	

SECURITY CLASSIFICATION

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

Source and Ref. Sync. Amp.

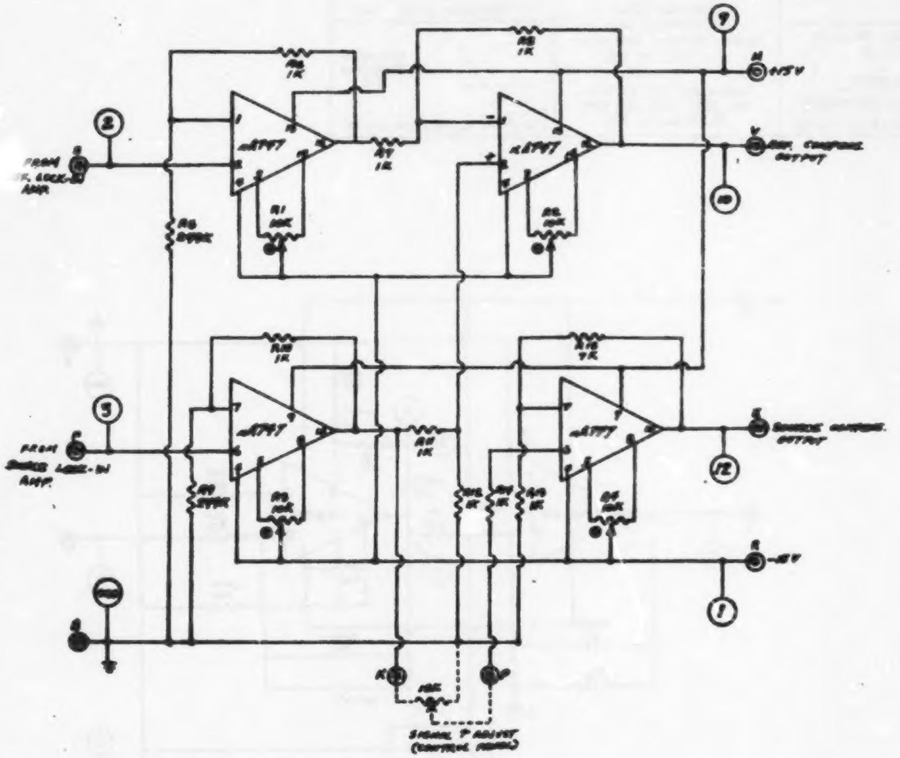
SIZE	CODE IDENT	DRAWING NO.
C	14170	596-722-026

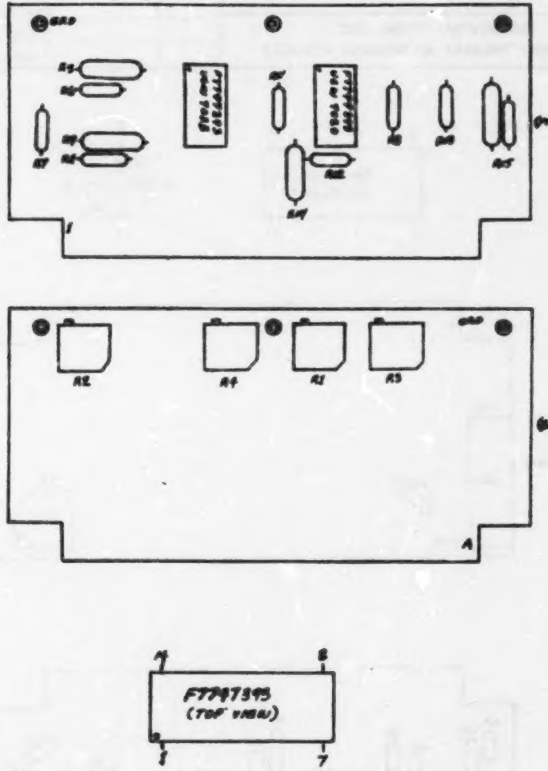
SCALE RELEASED SHEET 1 OF 1

PACKAGE NO. DOC DISTR FORM

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED





UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES √	SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS
RIVET BASIC CODE-NAS523	SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS
BB—MS20426AD BJ—MS20470AD	ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED PL ☐ FOR PARTS LIST UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES

.X	.XX	.XXX
± .1	± .03	± .010

ANGULAR PER 0-70902

MATL
PROD. ENGR
SECURITY CLASSIFICATION

CHECK
STRESS
GR ENGR
DESIGN
DRAWN R. ROLLINS
CONTRACT NO.

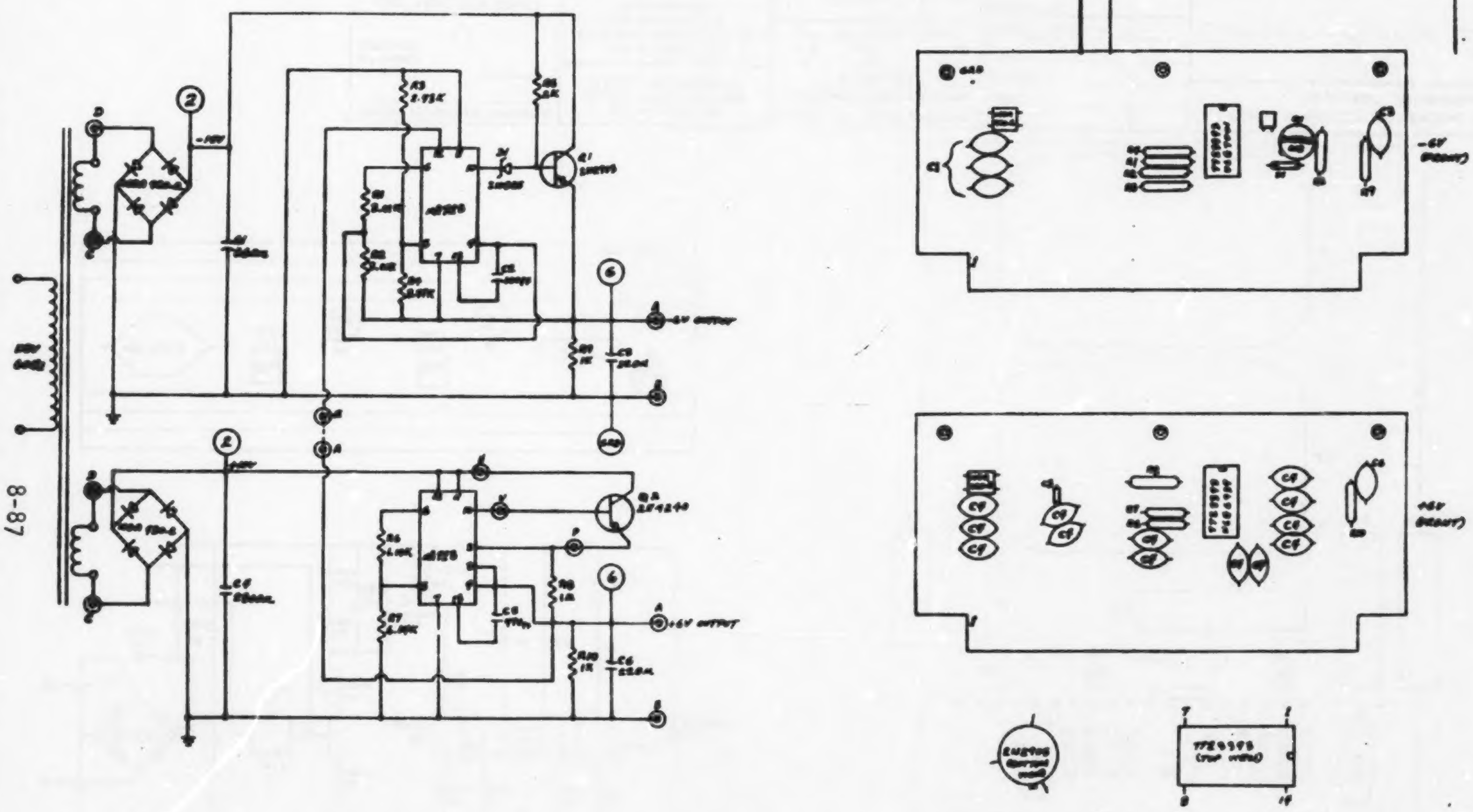
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

SOURCE AND REF COMPENS AMPS

SIZE	CODE IDENT	DRAWING NO.
C	14170	596-722-027

SCALE | RELEASED | SHEET 1 OF 1
PACKAGE NO. | DOC | DISTR | FORM

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

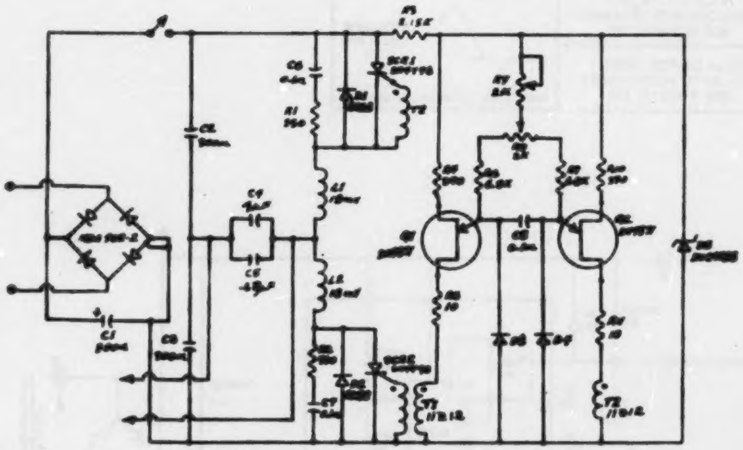


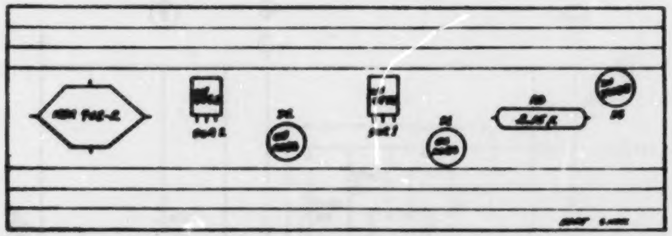
UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES √	SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES .X ± .1 .XX ± .03 .XXX ± .010 ANGULAR PER 0-70902	CHECK STRESS GR ENGR DESIGN DRAWN R. ROLLINS CONTRACT NO.	CONVAIR DIVISION OF GENERAL DYNAMICS SAN DIEGO, CALIFORNIA
RIVET BASIC CODE-NAS523 BR—MS20426AD BJ—MS20470AD	SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS			±6V POWER SUPPLY
	ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED PL ☐ FOR PARTS LIST UL ☐ FOR USAGE LIST	MATL PROD. ENGR		SIZE C CODE IDENT 14170 DRAWING NO. 596-722-028
				SCALE RELEASED SHEET 1 OF 1

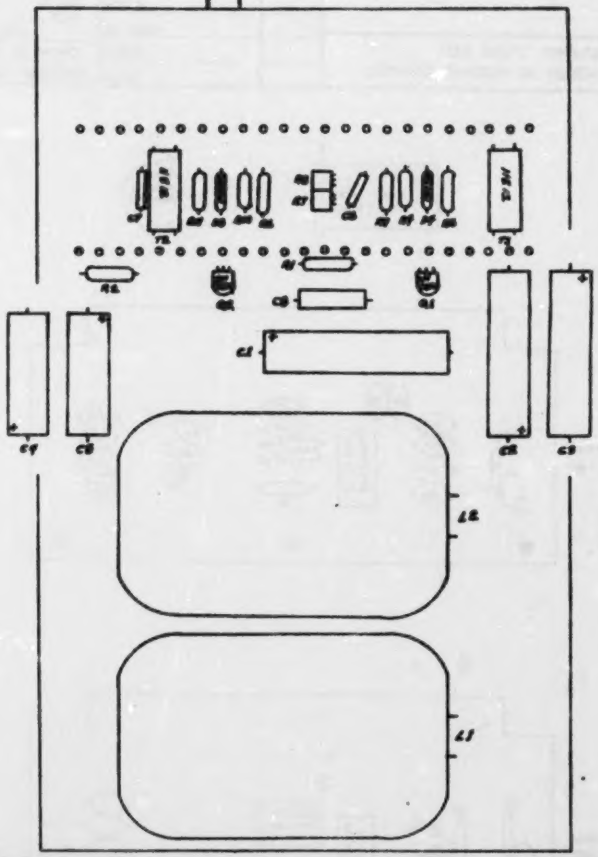
SECURITY CLASSIFICATION

PACKAGE NO.   DOC   DISTR   FORM 6617

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED







UNLESS OTHERWISE SPECIFIED	
ALL MACHINED SURFACES	√
RIVET BASIC CODE-NAS523	
BD—MS20426AD	
BJ—MS20470AD	

SEE 0—70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0—70802 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED
SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES

.X	.XX	.XXX
± .1	± .03	± .010

ANGULAR PER 0—70802

MATL
PROC. SHEET

SECURITY CLASSIFICATION

CHECK
STRESS
GR ENGR
DESIGN
DRAWN R. ROLLINS
CONTRACT NO.

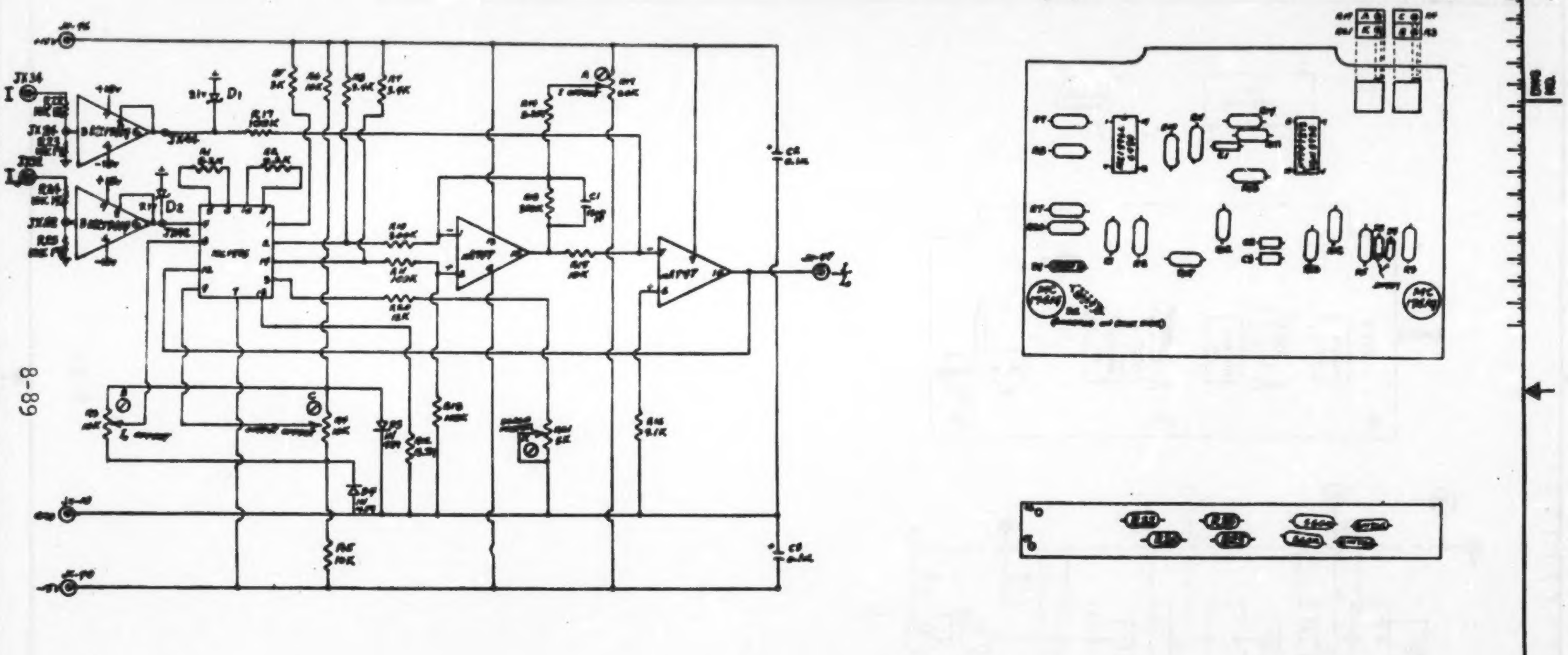
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

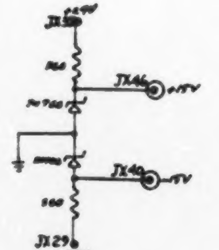
CHOPPER MOTOR DRIVE

SIZE	CODE IDENT	DRAWING NO.
C	14170	596-722-029

SCALE
RELEASED
SHEET 1 OF 1
PACKAGE NO.
DOC
DISTR
FORM

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED





UNLESS OTHERWISE SPECIFIED	
ALL MACHINED SURFACES	√
RIVET BASIC CODE-NAS523	
BB—MS20426AD	
BJ—MS20470AD	

SEE 0–70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0–70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES

.X	.XX	.XXX
± .1	± .03	± .010

ANGULAR PER 0–70902

MATL
PROD. ENGR

CHECK
STRESS
GR ENGR
DESIGN
DRAWN A. ROLLINS
CONTRACT NO.

SECURITY CLASSIFICATION

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

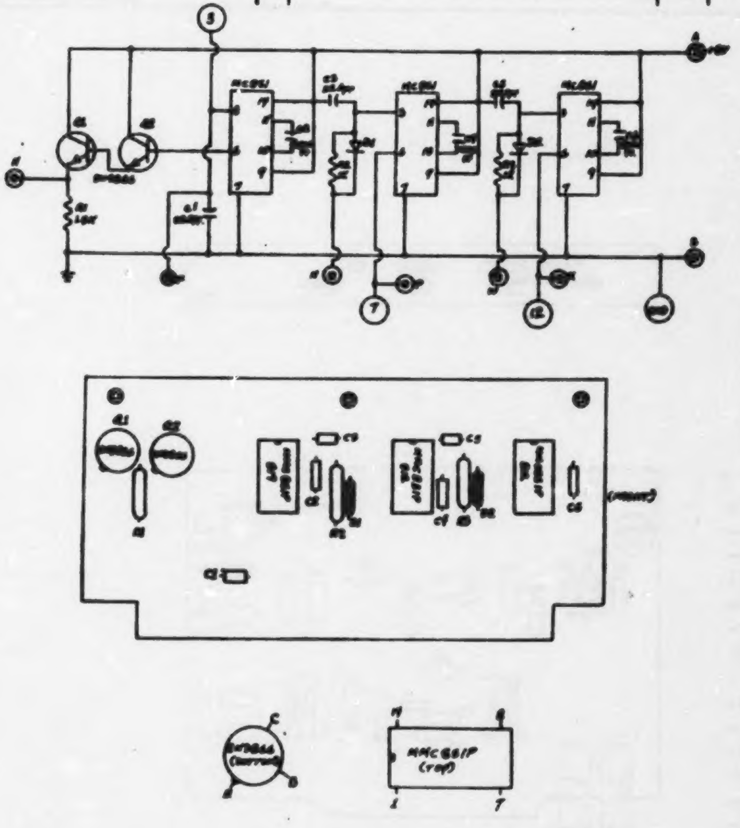
I/L RATIO MODULE

SIZE	CODE IDENT	DRAWING NO.
C	14170	596-722-030

SCALE
RELEASED
SHEET 1 OF 1
PACKAGE NO.
DOC
DISTR
FORM 6817

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

SH | LTR
DWG NO.



UNLESS OTHERWISE SPECIFIED	
ALL MACHINED SURFACES	√
RIVET BASIC CODE-NAS523	
BD—MS20426AD	
BJ—MS20470AD	

SEE 0—70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0—70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED
SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES

.X	.XX	.XXX
±.1	±.03	±.010

ANGULAR PER 0—70902

MATL
PROD. ENGR

CHECK	
STRESS	
GR ENGR	
DESIGN	
DRAWN	R. ROLLINS
CONTRACT NO.	

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

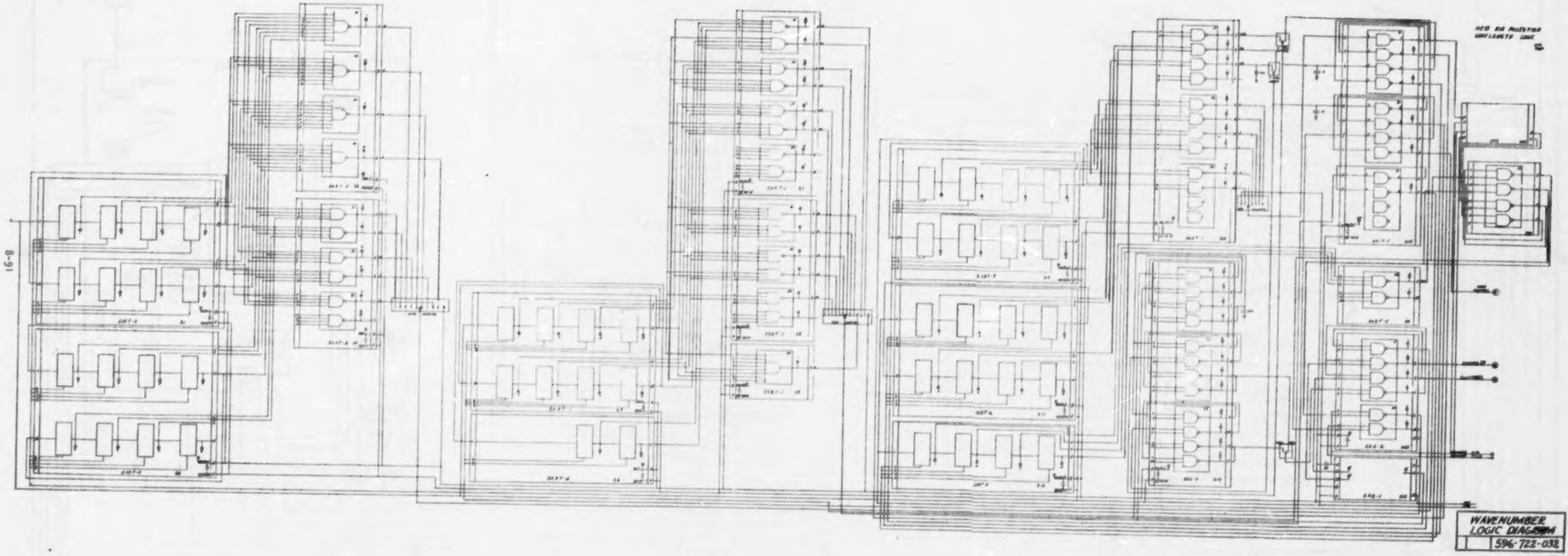
DATA CONTROL MONOSTABLE

SIZE	CODE IDENT	DRAWING NO.
C	14170	596-722-031

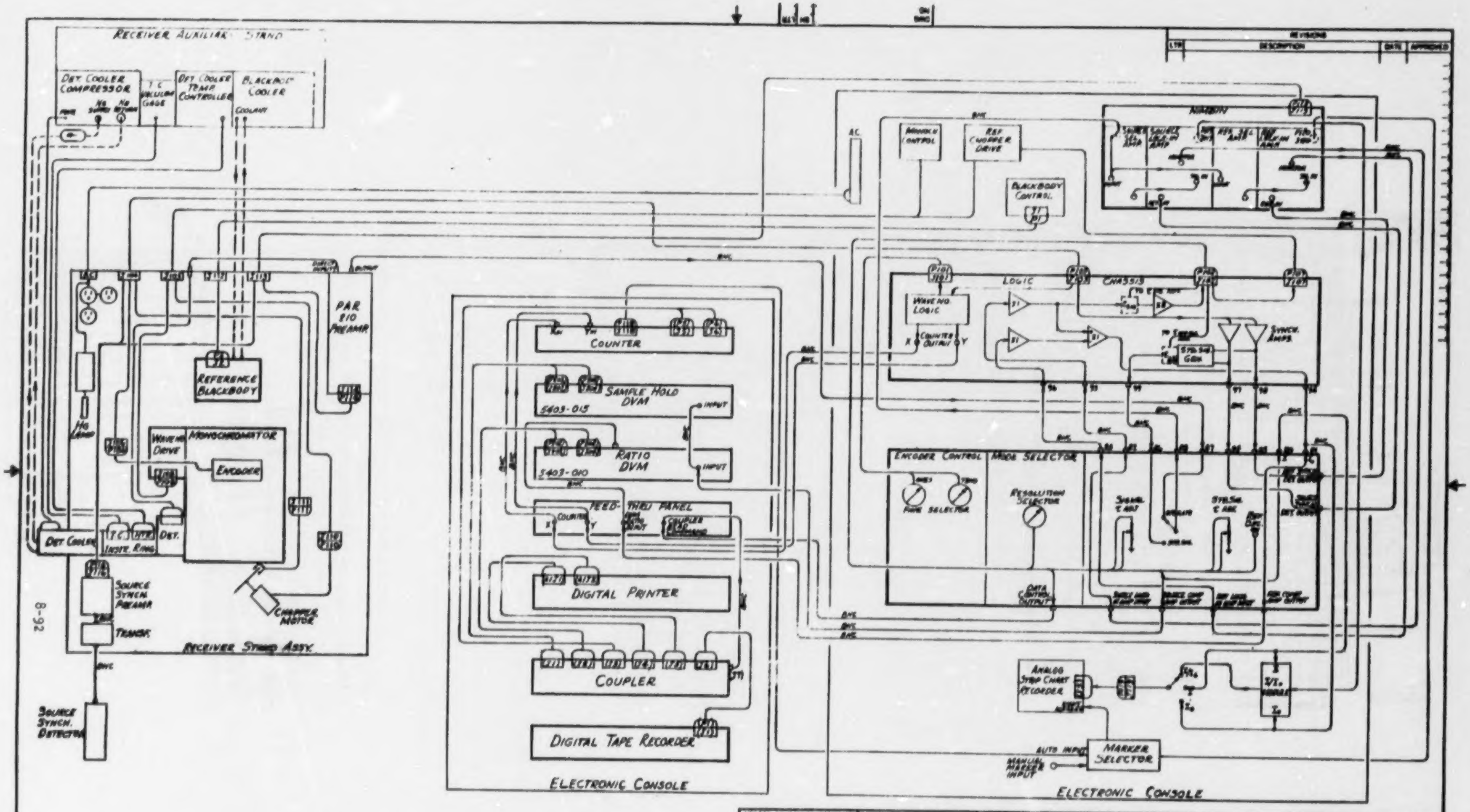
SCALE | RELEASED | SHEET 1 OF 1

PACKAGE NO. | DOC | DISTR | FORM 8517

SECURITY CLASSIFICATION



WAVENUMBER
LOGIC DIAGRAM
596-722-032



UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES √
RIVET BASIC CODE-MS20426AD
BB—MS20426AD
BJ—MS20470AD

SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ± .1 .XX ± .03 .XXX ± .010
ANGULAR PER 0-70902

CHECK
STRESS
GR ENGR
DESIGN
DRAWN M. Brewer 1/31/66
CONTRACT NO.

SECURITY CLASSIFICATION

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

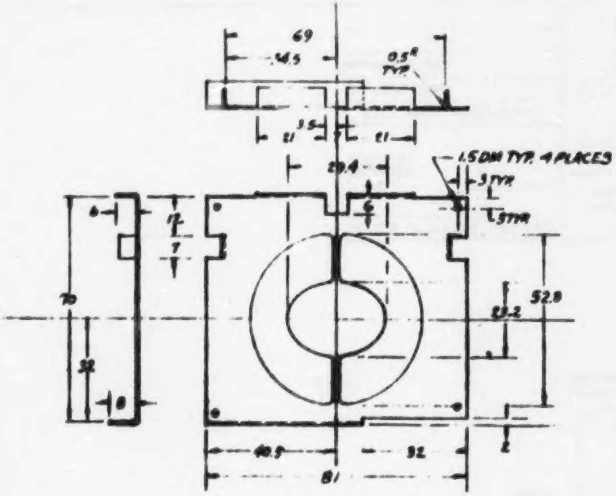
INTERCONNECTION DIAGRAM

SIZE D | CODE IDENT 14170 | DRAWING NO. 596-722-033

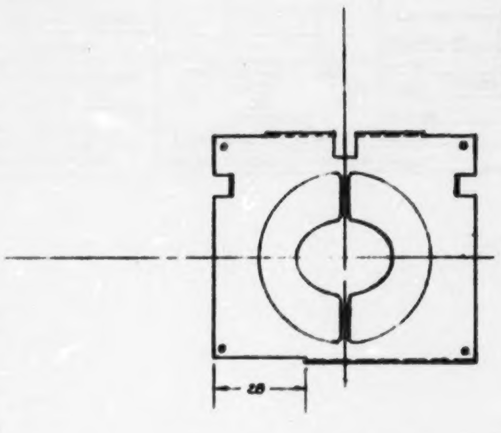
SCALE — RELEASED SHEET 1 OF 1
PACKAGE NO.

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED



DETAIL -1



DETAIL -2

SAME AS -1 EXCEPT AS SHOWN

NOTES:

1. ALL DIMENSION IN MM. ± 0.5 EXCEPT CUTOUT DIM. ± 0.2MM.
2. BLACK ANODIZE -1 & -2.
3. CENTRAL FIGURE IS AN ELLIPSE.

REQ PER ASSY / INSTL	UNIT OF MEAS	ITEM OR FIND NO.	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT
1				-2	101 MASK	.025 × 3.5 × 3.5 ALUMINUM 2024-0 QQ-A-355
1				-1	240 MASK	.025 × 3.5 × 3.5 " " " "

NOTE SYMBOL: E—END ITEM G—GENERAL NOTE L—LIMIT M—MATERIAL R—REFERENCE DESIGNATION S—STOCK NO. U—USAGE DATA

PARTS LIST

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES √
RIVET BASIC CODE-MS20426AD
BB—MS20426AD
BJ—MS20470AD

SEE 0—70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0—70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ± .1 .XX ± .03 .XXX ± .010
ANGULAR PER 0—70902
MATL
PROD. ENGR

CHECK
STRESS
GR ENGR
DESIGN
DRAWN
CONTRACT NO.

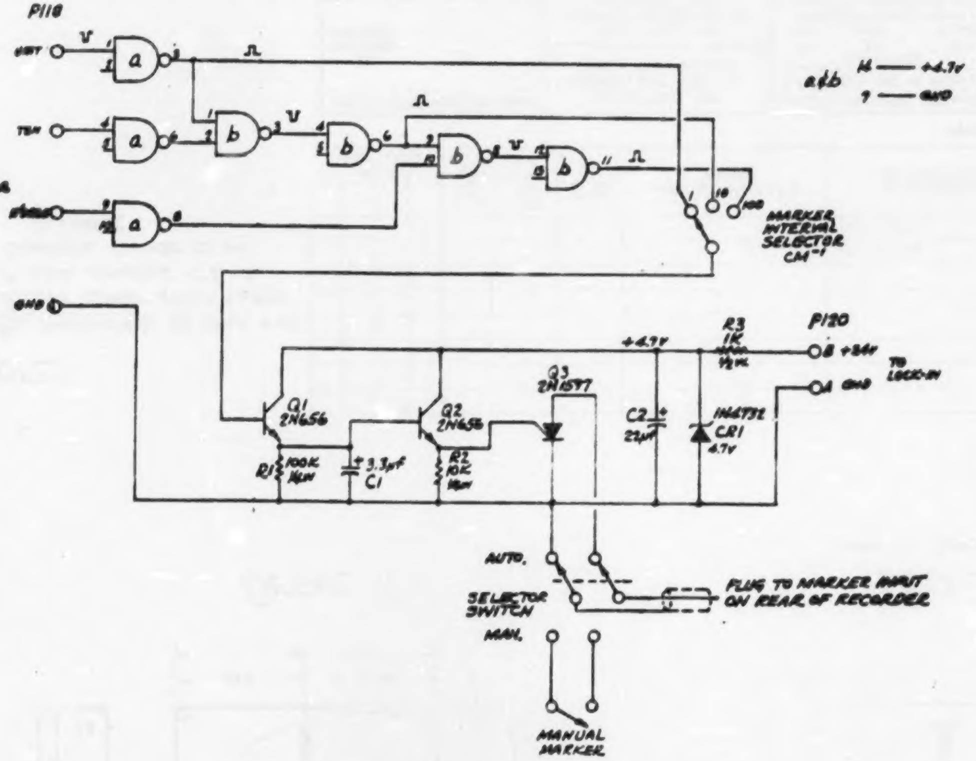
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

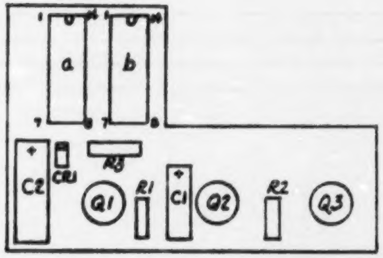
GRATING MASKS

SIZE C
CODE IDENT 14170
DRAWING NO. 596-722-034
SCALE
RELEASED
SHEET 1 OF 1
PACKAGE NO.
DOC
DISTR
FORM

SECURITY CLASSIFICATION

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED





UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES √
RIVET BASIC CODE-NAS523
BB—MS20426AD
BJ—MS20470AD

SEE 0–70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS
SEE 0–70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS
ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
PL ☐ FOR PARTS LIST
UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
.X ±.1 .XX ±.03 .XXX ±.010
ANGULAR PER 0–70902
MATL
PROD. ENGR

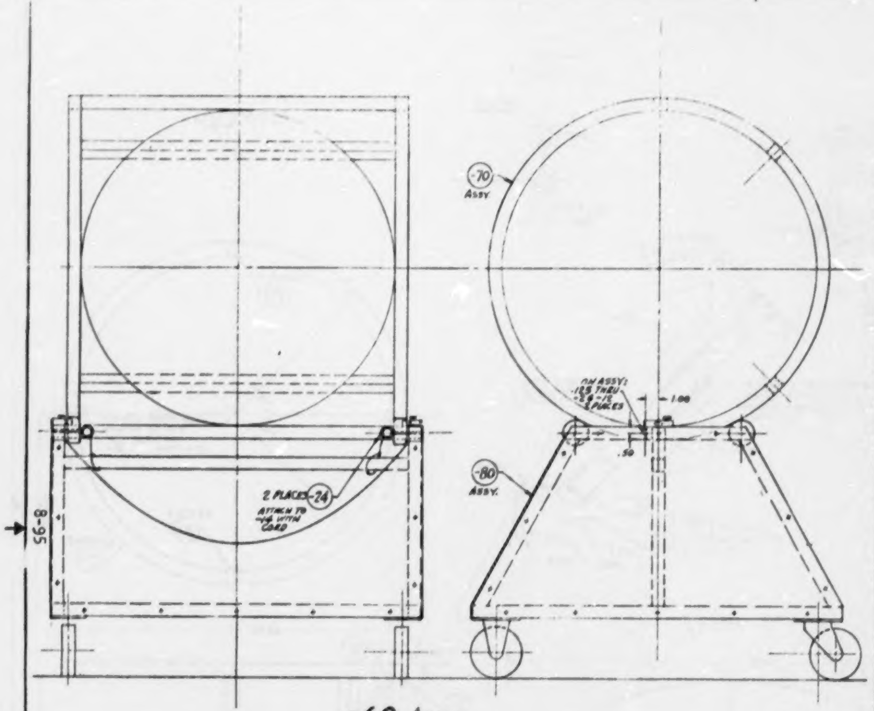
CHECK
STRESS
GR ENGR
DESIGN M. STREIFF 4/21/72
DRAWN
CONTRACT NO.

CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

RECORDER MARKER SELECTOR

SIZE C CODE IDENT 14170 DRAWING NO. 596-722-035
SCALE — RELEASED SHEET 1 OF 1
PACKAGE NO. DOC DISTR FORM 6517

SECURITY CLASSIFICATION


-70 ASSY
-80 ASSY.
ON ASSY: .125 THRU .38-.12 2 PLACES
1.00
.50
2 PLACES -24 ATTACH TO -14 WITH CORD
8-95

-60 ASSY

DETAIL -24
FULL SIZE

NOTES:

1. BREAK ALL SHARP CORNERS APPROX .02 × 45°.
2. PAINT ALUM. PARTS BORG WARNER EMCOR II EN2-60 (GOLD)
3. WELD FILLER MATERIAL SHALL BE 4043 OR 5356.
4. UNLESS SPECIFIED, ALUM. PARTS MAY BE ANY ALLOY (ANY COND. EXCEPT 0)
5. UNLESS OTHERWISE INDICATED, 3/16" FILLET WELD ALL AROUND.
6. -1 TO BE ALUMINIZED + 1/4 WAVE (VISIBLE) OF SiO. (BY DEPT 621-0)
7. OUTSIDE SURFACES OF WELDS ON -90 ASSY TO BE FLUSH (FOR PANEL INSTALL.)
8. TO REMOVE -70 ASSY FROM -80 ASSY DISCONNECT SPRINGS AT LOWER ATTACHMENT, REMOVE -21 STOP AND -23 PIN BOTH SIDES.
9. TIGHTENING THUMBSCREW WILL INCREASE ROLLING RESISTANCE.
10. LOCK PINS SHOULD BE INSERTED DURING TRANSPORT.

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

-90	-80	-70	-60	UNIT OF MEAS	ITEM OR FIND NO	CODE IDENT NO	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	(STOCK SIZE, MATERIAL, SPECIFICATION, TYPE (TEMPER, ETC.), HEAT TREAT) NOTE TEXT
	2						BASSICK M716	RIGID CASTER 4" DIA	
	2						BASSICK SBM706	SWIVEL CASTER 4" DIA	WITH SIDE WHEEL BRAKE
	4						BASSICK WP9009	CASTER WHEEL 2" DIA × 11/16	1/4" AXLE 15/16" HUB PHENOLIC TREAD
			1				-70	ASSY.	
			1				-80	ASSY.	
	1						-90	ASSY.	
	8							#8 WASHERS × .06" THICK	
	50 APPROX							#6 SELF TAPG .10 SCREWS	CRES. STEEL
	8							#8 EXT TOOTH LOCKWASHER	
	2							#8-32 THUMBSCREW	
	2							#6-32 NUT	
	2							#6 INT TOOTH LOCKWASHER	
	2							#6-32 × .19 BINDING HD SCREW	
	4							#6-32 × .75 F.H. SCREW	
	6							#6-32 × .5 F.H. SCREW	
	16							1/4" NUT	
	16							1/4" LOCKWASHER	
	4							1/4" × 3/4" R.H. BOLT	
	12							1/4" × 1 1/2 R.H. BOLT	
		BULK						.06" THICK CORK	
		20						#8-32 × 0.5 R.H. SCREW	
			2				-24	LOCKPIN	.12 DIA. WIRE × 6"
	2						-23	PIN	MAKE FROM #10-32 PHILLIPS HEAD CRES. SCREW
	2						-22	SPRING	.0475 DIA STAINLESS STEEL WIRE SPRING TEMPER
	2						-21	STOP	.05 × 1 × 1 ALUM. 2024-T351 PLATE QQ-A-355
	2						-20	ROLLER	.62 DIA × 1 BRASS ROD 1/2 HARD QQ-B-626 COMP 22 OR EQUIV
	2						-19	ARM	.05 × 1 × 2 ALUM 2024-T351 PLATE QQ-A-355
	2						-18	BRACKET	MAKE FROM 1 × 1 × .125 WALL × 3 ALUM. TUBE
	4						-17	PIN	.38 DIA. × 2.5 300 SERIES STAINLESS STEEL
	2						-16	PANEL	.064 × 19 × 30 ALUM.
	2						-15	PANEL	.064 × 16 × 30 ALUM.
1							-14	BRACE	1 × 1 OTS × .125 WALL × 29 6063-T5 ALUM. QQ-A-200/9
2							-13	TUBE	× 14
2							-12	TUBE	× 15
4							-11	TUBE	× 17
4							-10	BRACE	× 9
2							-9	TUBE	× 28
2							-8	TUBE	1 × 1 OTS × .125 WALL × 30 6063-T5 ALUM QQ-A-200/9
							-7	SPACER	.25 × 1.1 × 1.1 ALUM.
		2					-6	CLIP	.064 × 1.2 × 1.5 ALUM.
		2					-5	CLIP	.064 × 1.2 × 1.5 ALUM.
		4					-4	CLIP	.064 × 1 × 2 ALUM.
		4					-3	BRACE	1 × 1 OTS × .125 WALL × 25" 6063-T5 ALUM. QQ-A-200/9
		2					-2	RING	1 × 1 OTS × .125 WALL × 170" 6063-T5 ALUM. QQ-A-200/9
		1					-1	MIRROR	38 × 27.62 × 34.92 ELLIPSE PLATE GLASS CUT TO TEMPLATE

REQ PER ASSY / INSTL

NOTE SYMBOL: E—END ITEM G—GENERAL NOTE L—LIGHT M—MATERIAL R—REFERENCE DESIGNATION S—STOCK NO. U—USAGE DATA

PARTS LIST

UNLESS OTHERWISE SPECIFIED
ALL MACHINED SURFACES √

RIVET BASIC CODE NAS523
BB—MS20426AD
BJ—MS20470AD

SEE 0-70014 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70002 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED
UA ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
X ± .1 XX ± .03 XXX ± .010
ANGULAR PER 0-70002

MAT.
PROD. SHIFT

SECURITY CLASSIFICATION

CHECK
STRESS
GR ENGR
DESIGN Al Drewry 5/6/71
DRAWN
CONTRACT NO.

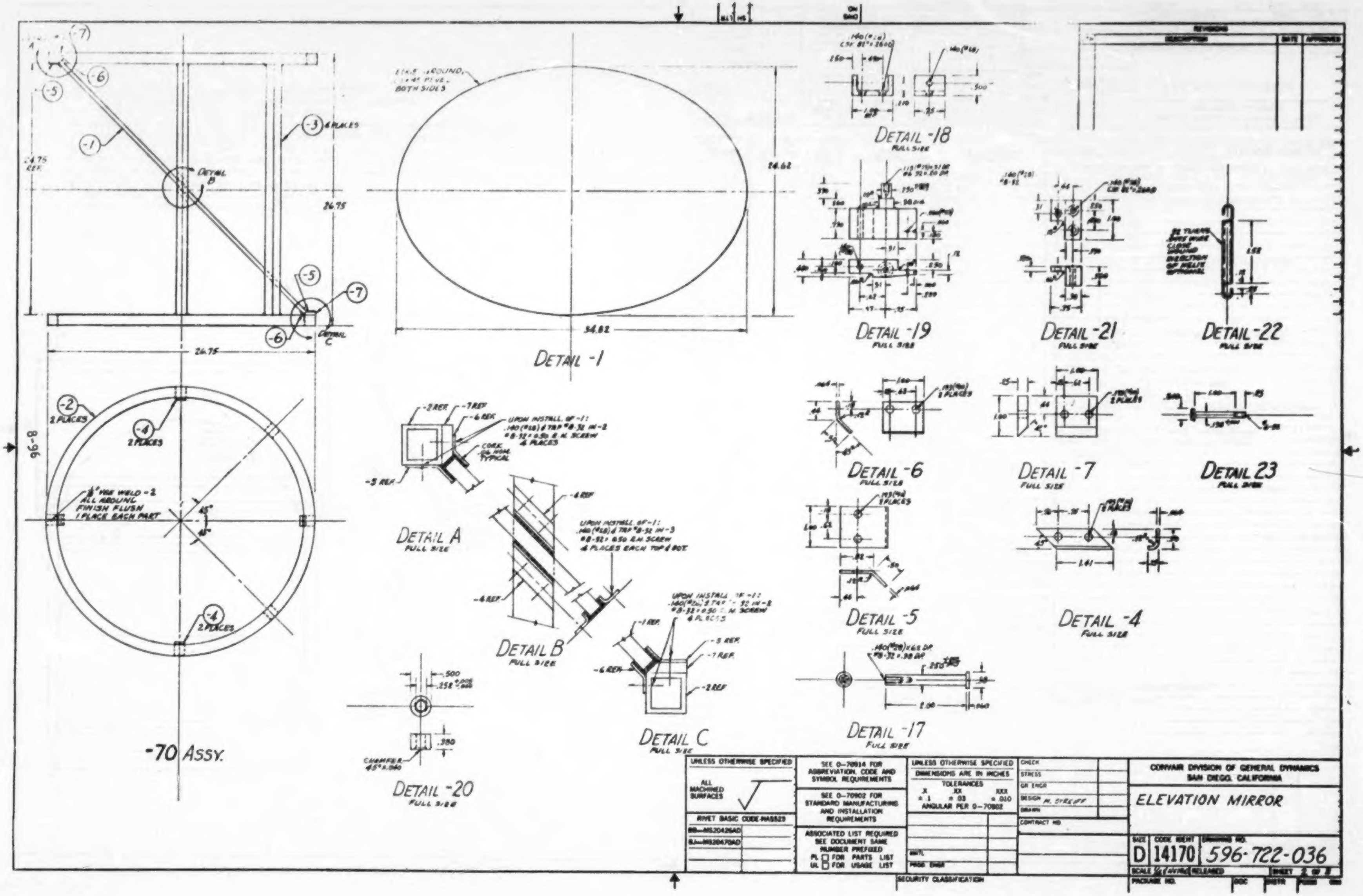
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

ELEVATION MIRROR

SIZE D CODE IDENT 14170 DRAWING NO. 596-722-036

SCALE 1/8 APPROX RELEASED SHEET 1 OF 2

PACKAGE NO.



UNLESS OTHERWISE SPECIFIED

ALL MACHINED SURFACES √

RIVET BASIC CODE-NAS523

BB—MS20426AD

BJ—MS20470AD

SEE 0-70914 FOR ABBREVIATION, CODE AND SYMBOL REQUIREMENTS

SEE 0-70902 FOR STANDARD MANUFACTURING AND INSTALLATION REQUIREMENTS

ASSOCIATED LIST REQUIRED SEE DOCUMENT SAME NUMBER PREFIXED

PL ☐ FOR PARTS LIST

UL ☐ FOR USAGE LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES

X	XX	XXX
± .1	± .03	± .010

ANGULAR PER 0-70902

MATL

PROD ENGR

SECURITY CLASSIFICATION

CHECK

STRESS

GR ENGR

DESIGN M. STREIFF

DRAWN

CONTRACT NO

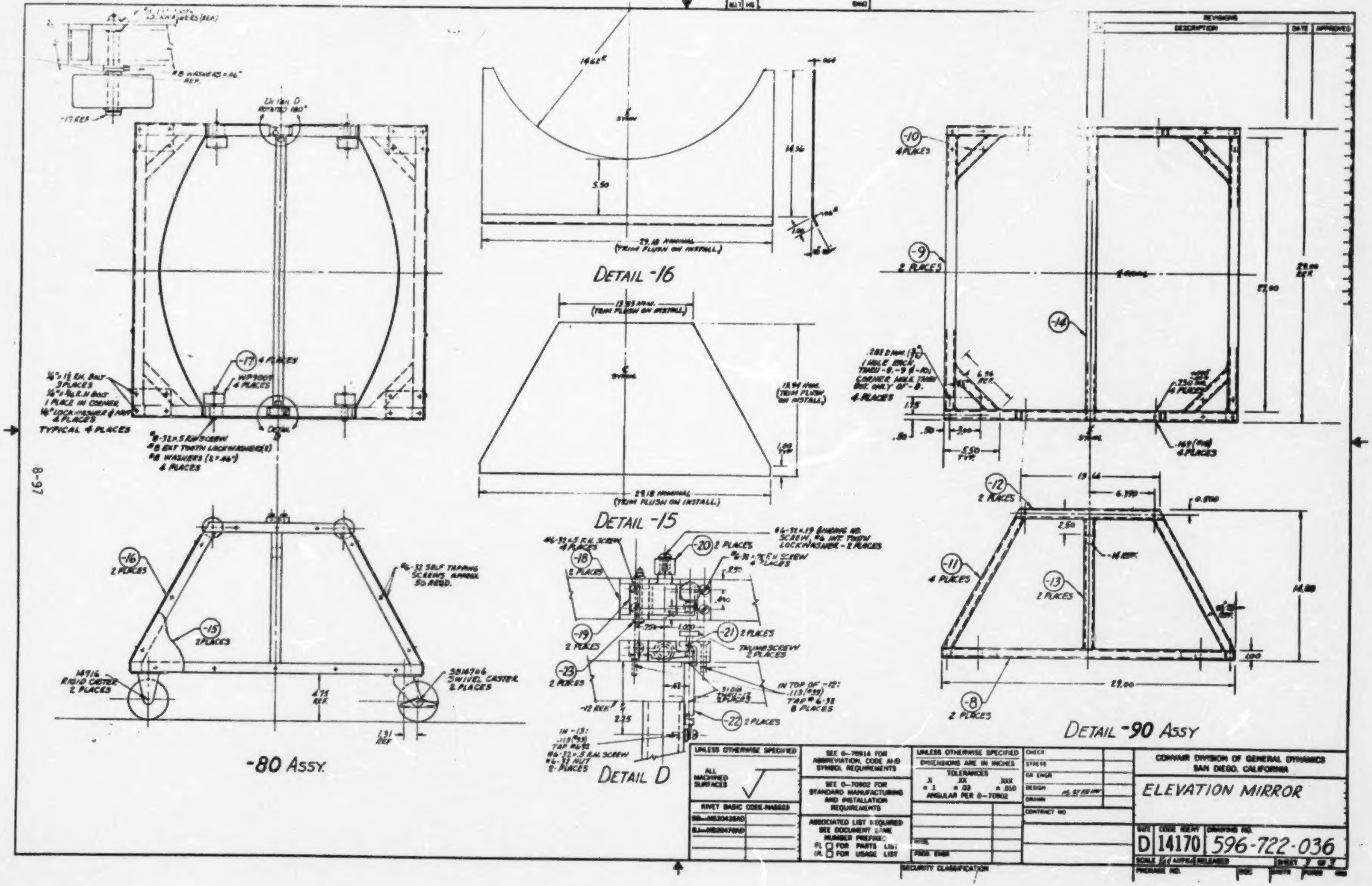
CONVAIR DIVISION OF GENERAL DYNAMICS
SAN DIEGO, CALIFORNIA

ELEVATION MIRROR

SIZE D CODE IDENT 14170 DRAWING NO. 596-722-036

SCALE RELEASED SHEET 2 OF 2

PACKAGE NO. DOC DISTR


-80 Assy.
Detail -16
Detail -15
Detail D
Detail -90 Assy
Detail D rotated 180°
#8 washers x .06" ref.
-17 ref
-17 4 places
WP3007 4 places
1/4" x 1 1/2 R.H. bolt 3 places
1/4" x 1 3/4 R.H. bolt 1 place in corner
1/4" lockwasher & nut 4 places
Typical 4 places
#8-32 x .5 R.H. screw
#8 ext tooth lockwashers (2)
#8 washers (2 x .06")
4 places
-16 2 places
-15 2 places
#6-32 self tapping screws approx. 50 reqd.
14916 rigid caster 2 places
3814766 swivel caster 2 places
4.75 ref.
1.31 ref
14.62 R
5.50
14.36
29.18 nominal (trim flush on install.)
13.83 nom. (trim flush on install.)
13.94 nom. (trim flush on install.)
1.00 typ
#6-32 x .5 F.H. screw 4 places
-18 2 places
-20 2 places
#6-32 x .19 binding hd. screw, #6 int. tooth lockwasher - 2 places
#6-32 x .5 F.H. screw 4 places
-19 2 places
-21 2 places
Thumbscrew 2 places
-23 2 places
In top of -12: .113 (#33) tap #6-32 8 places
-22 2 places
-12 ref
2.25
In -13: .113 (#33) tap #6-32 #6-32 x .5 R.H. screw #6-32 nut 2 places
-10 4 places
-9 2 places
-14
.283 diam. (9/32) 1 hole each thru -8, -9 & -10; corner hole thru bot. only of -8. 4 places
6.96 ref.
1.75
.50
3.00
5.50 typ.
.250 4 places
.169 (#18) 4 places
17.00
29.00 ref
-12 2 places
13.44
6.390
0.500
2.50
-11 4 places
-13 2 places
14.00
29.00
.100
-8 2 places
Unless otherwise specified
All machined surfaces
Rivet basic code-NAS523
See 0-70914 for abbreviation, code and symbol requirements
See 0-70902 for standard manufacturing and installation requirements
Associated list required see document same number prefixed
PL ☐ for parts list
UL ☐ for usage list
Unless otherwise specified dimensions are in inches
Tolerances .X ±.1 .XX ±.03 .XXX ±.010
Angular per 0-70902
Check
Stress
Gr engr
Design
Drawn
Contract no
Proj. engr
Security classification
Convair Division of General Dynamics San Diego, California
ELEVATION MIRROR
Size D
Code ident 14170
Drawing no. 596-722-036
Scale
Released
Sheet 2 of 2
Package no.